PATENT ABSTRACTS OF JAPAN

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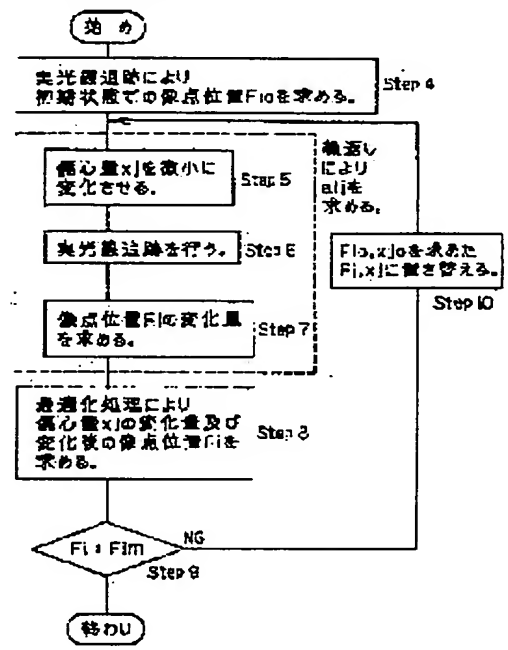
(54) PHYSICAL QUANTITY MEASURING METHOD OF OPTICAL ELEMENT OR OPTICAL SYSTEM

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a method which enables highly accurate determination of parameters indicating the eccentricity of an optical system comprising a single optical element or the combination of the optical elements.
SOLUTION: In the eccentricity measuring method, rays are made incident into an optical element or an optical system to be measured and the angle of the rays with the optical axis thereof is varied to detect the position of the rays reflected or refracted from a surface to be detected with respect to each of the angles. A real ray tracing is performed for each of the resulting states to optimize the eccentricity so that a difference is smaller between the position of the rays measured for all of the states and the position of the rays obtained by the ray tracing thereby determining at least one eccentricity.



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CLAIMS

[Claim(s)]
[Claim 1] The optical element which carries out incidence of the light to a measuring beam-ed study component or optical system, and is characterized by calculating the physical quantity of said optical element or optical system by measuring the condition of the light injected from the optical element or optical system, and using a real ray trace from the measured value, or the physical quantity measuring method of optical system.
[Claim 2] The optical element characterized by the image formation relation in the case of measuring the image of the flux of light using any of actual size image formation or inequality twice image formation they are, or the physical quantity measuring method of optical system.
[Claim 3] Carry out incidence of the beam of light to a measuring beam-ed study component or optical system, and the include angle of this beam of light and optical axis to make is changed variously. By optimizing physical quantity so that the difference of the location of the beam of light which detected the location of the beam of light reflected or refracted from a specimen plane to each include angle, and was measured in all conditions, and the beam-of-light location for which it asked with ray tracing may become small The optical element characterized by calculating at least one physical quantity, or the physical quantity measuring method of optical system.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to an optical element or the physical quantity measuring method of optical system.
[0002]
[Description of the Prior Art] As a measuring method of the eccentricity of a general lens system, the autocollimation method is conventionally known in the physical quantity (a configuration, radius of curvature, a spacing, an aspheric surface multiplier, refractive-index distribution, etc. are included) of a lens system. An autocollimation method is an approach of making the same location as the projection location of the index producing a twice as many reflected image, such as projecting an index on the location of the image of the center of curvature on the appearance of the field which it is going to measure, i.e., the center of curvature of the measuring plane-ed by which image formation is carried out in another field which exists between a measuring plane-ed and an observation system, and being based on a specimen plane, as this.
[0003] Although an index image will be formed on this reference axis if there is no eccentricity in all lens sides about a metrics shaft in the above-mentioned case, a reflected image will be formed in the location separated from the reference axis in the perpendicular direction to the reference axis if eccentricity exists in which lens side. Since the amount delta of deflections from the reference axis of this reflected image has each eccentricity epsilon and functional relation of a lens side, if the amount delta of deflections of the actual size reflected image of the index image projected on the ball center location of that appearance about each lens side is measured, the eccentricity of each lens side over that metrics shaft can be calculated by count.
[0004] Drawing 7 is the schematic diagram which was produced by the measuring plane 51-ed [1] with eccentricity (inclination of a shaft) epsilon and in which having swayed and having shown the amount delta. Incidence is carried out so that the flux of light from the light source (index) 52 may be completed by the collimator lens 53 and it may converge on the ball center location on the metrics shaft of the measuring plane 51-ed like drawing 7 . When the convergence location of the flux of light and the ball center location of the measuring plane 51-ed are in agreement, vertical incidence of the flux of light will be carried out to the measuring plane 51-ed. however, the convergence location of the flux of light and the ball center location of the measuring plane 51-ed are in agreement — **** (the measuring plane 51-ed is carrying out epsilon eccentricity) — oblique incidence of the flux of light will be carried out to the measuring plane 51-ed. Here, the reflected light which occurred in the measuring plane 51-ed in the case of vertical incidence will go back, and will converge the optical path at the time of incidence on the light source (index) 52 and a location [****]. On the other hand, the reflected light which occurs in the measuring plane 51-ed in the case of oblique incidence is converged on the location [location / which shifted from the optical path at the time of incidence, and was converged when vertical incidence was carried out] delta Shifted.
[0005]
[Problem(s) to be Solved by the Invention] However, in the above-mentioned conventional technique, since it carried out when it was measured in the image surface 54, and it sways and the relation between an amount delta and the eccentricity epsilon of the lens side 51 was proportional, and it was asking for the proportionality coefficient of this proportionality by paraxial count, the precision of the eccentricity epsilon obtained by count might fall. If the relational expression of the amount delta of deflections and the eccentricity epsilon of the measuring plane 51-ed sets the radius of curvature of the measuring plane 51-ed to r when the scale factor beta for which it asked by paraxial count of a collimator lens 53 shown in drawing 7 is used
delta=2betarepsilon ... (1)
It becomes.
[0006] This invention is made in view of such a problem of the conventional technique, and the purpose is offering the technique of asking for the parameter showing physical quantity including the eccentricity of the optical system which consists of the simple substance or combination of an optical element in a high precision.
[0007]
[Means for Solving the Problem] The optical element of this invention which attains the above-mentioned purpose, or the eccentric measuring method of optical system is an approach which carries out incidence of the light to a measuring beam-ed study component or optical system, and is characterized by calculating the eccentricity of said optical element or optical system by measuring the condition of the light injected from the optical element or optical system, and using a real ray trace from the measured value.
[0008] Another optical element of this invention or the eccentric measuring method of optical system is an approach characterized by the image formation relation in the case of measuring the image of the flux of light using any of actual size image formation or inequality twice image formation they are.
[0009] This invention further another optical element or the eccentric measuring method of optical system Carry out incidence of the beam of light to a measuring beam-ed study component or optical system, and the include angle of this beam of light and optical axis to make is changed variously. By optimizing eccentricity so that the difference of the location of the beam of light which detected the location of the beam of light reflected or refracted from a specimen plane to each include angle, and was measured in all conditions, and the beam-of-light location for which it asked with ray tracing may become small It is the approach characterized by calculating at least one eccentricity.
[0010]
[Embodiment of the Invention] Hereafter, the principle and example of the optical element of this invention or the eccentric measuring method of optical system are explained.

[0011] This invention uses a real ray trace for the measured processing which sways and computes the eccentricity of a field from an amount delta, in order to solve the aforementioned trouble. A real ray trace is also called real ray tracing. It is the approach of calculating the location of a beam of light, a direction, etc. by calculating refraction and the law of reflection strictly. Ray tracing in consideration of the eccentricity of optical system and the aspheric surface is possible, and it is widely used for the design of the optical system using a computer, evaluation, etc.
[0012] the position vector P0 of the beam of light which carries out incidence to optical system as processing of a real ray traced is shown in drawing 1 , and direction vector R0 from — intersection P1 with the 1st page (field at which a beam of light is crossed first) of optical system asking — normal vector H1 of the field in an intersection location from — the incident angle thetai1 of a beam of light is decided. Refractive index n0 of the medium by the side of incidence Refractive index n1 by the side of injection A Snell's law is used and they are the angle of emergence thetao1 and the direction vector R1 of a injection beam of light. It can be found. The position vector P1 of the intersection of the 1st page, and direction vector R1 of a injection beam of light It is made the incident ray to the 2nd page (field at which a beam of light is crossed next), and repeats and asks for the intersection with the next field, and the injection beam of light.
[0013] It is possible to be able to calculate how in optical system, and the flux of light or the beam of light which carried out incidence to optical system is injected, and to compute the various properties of optical system, such as the flux of light or the image point location of a beam of light, the center-of-gravity location of the flux of light, a condition (magnitude, form) of the flux of light, the direction and the location of a beam of light, a condition (reinforcement, polarization condition) of a beam of light or breadth of the flux of light, and the amount of local paraxials (JP,11-287947,A), by the real ray trace.
[0014] It sways and an amount delta is measured by the measurement machine which consists of optical system which was raised with aforementioned Object of the Invention, and which is shown in drawing 6 . The amount delta of deflections becomes the processing which asks for an image point location or the center-of-gravity location of the flux of light. The beam of light (chief ray) which came out from the object point (semiconductor laser) 201 and which extracts and passes along a core is projected one by one to the center of curvature of each field of the measured lens 203 through the optical system 202 for measurement, and a beam splitter 204, this reflected light is pursued to the image surface (light-receiving side of CCD camera 207), and the coordinate value in the image surface (light-receiving side of CCD camera 207) is calculated. A drawing core here may also choose an intersection with the center-of-rotation shaft of not only the core of drawing of a ****-ed riser lens system (measured lens 203) but a specimen plane, an optical axis, a global coordinate, or the image rotator 205 etc. Moreover, the center-of-gravity location of the flux of light and a configuration pursue two or more beams of light which came out from the object point (semiconductor laser) 201, and ask for the injection beam of light from optical system (optical system for measurement) 202, respectively. The center-of-gravity location of the flux of light in the image surface (light-receiving side of CCD camera 207), magnitude, a form, etc. are searched for from the location of a injection beam of light, the reinforcement of a direction and a beam of light, etc.
[0015] The reinforcement of the beam of light can be found because energy permeability and a reflection coefficient of sound energy intensity can be found with the refractive index before and behind the incident angle to the field of a beam of light, the angle of emergence, and a field and the reinforcement of a beam of light and a polarization condition multiply the energy permeability or reflection coefficient of sound energy intensity after injection of each side. When coating processing has been performed to the field, permeability and a reflection factor can be computed using the property matrix for each class. Moreover, it is computable in a polarization condition pursuing Jones vector using the above-mentioned transmission and a reflection factor (refer to "principle of optics" Tokai University publication, "crystal optics" Japan Society of Applied Physics optical gathering for friendly discussion, and "optical thin film" KYORITSU SHUPPAN).
[0016] Hereafter, one example of the optical element of this invention or the eccentric measuring method of optical system is explained.
[0017] The block diagram of the processor which enforces an eccentric measuring method to drawing 2 is shown. This equipment consists of processing units 1 which carry out generalization processing of 6 and them, and process, such as the storage 4, such as the input devices 3, such as the measurement machine 8 which measures the condition of the image of the above flux of lights, or the condition of a beam of light, an indicating equipment 2, and a keyboard, and a magnetic disk, and a printer. In addition, it connects with LAN7 for exchanging the optical element measurement machine 9, external optical-system design equipment 10 grade and data, an art, etc., and the I / O unit with the external media 5, such as a floppy (trademark) disk and a magneto-optic disk, also has.
[0018] From the measurement machine 8, the spacing data about a measuring beam study system besides the measurement data of the condition of the image of the flux of light injected from a test optical system or the condition of a beam of light, movement magnitude, etc. are sent as mentioned above.
[0019] The optical element measurement machine 9 is the set of various measurement machines, such as a field configuration of an optical element, a spacing, a refractive index of a medium, and coating thickness, and the measurement data of r, d, and n of a test optical system and a measuring beam study system or coating data, manufacture error data, etc. are sent from this measurement machine 9. Here, they are r:curvature or radius of curvature (in the case of the aspheric surface, it is the equation of a field), d:spacing, the refractive index of n:medium, the complex index of refraction of coating data:each film, and thickness.
[0020] Optical-system design equipment 10 is equipment which designs optical system. From this equipment, design value data of a test optical system and a measuring beam study system, such as r, d, and n, etc. are sent. Moreover, it is possible to incorporate the eccentric data for which it asked from the approach of this invention, and for it to be reflected in a design, or to evaluate optical system.
[0021] Processing shown in drawing 3 with the equipment of drawing 2 is performed. Namely, the test optical system used for eccentricity calculation processing of Step2 from the input unit 3 of drawing 2 , storage 4, an external medium 5, the measurement machine 8, the optical element measurement machine 9, and optical-system design equipment 10 in Step1, r of a measuring beam study system, d (the spacing movement magnitude for the measurement in a measuring beam study system is also included). The class of n data, coating data, manufacture error data, the condition data of the image of the flux of light injected from a test optical system or the measurement data of the condition of a beam of light, the already known eccentric data, and eccentricity for which it asks, the range, etc. are inputted if needed.
[0022] In Step2, based on the various data inputted by Step1, the arithmetic unit 1 of drawing 2 performs a real ray trace, and the eccentricity to calculate is computed.
[0023] In Step3, the calculated eccentricity is outputted to the display 2 of drawing 2 , storage 4, an external medium 5, and a printer 6. Or data transfer is carried out to the measurement machine 8, the optical element measurement machine 9, and

optical-system design equipment 10 grade.
[0024] Next, the example which used the real ray trace for the solution method of the simultaneous equations of drawing 4 explains processing of the part equivalent to the eccentricity calculation processing Step2 of drawing 3 . If it applies to the eccentric measurement using the conventional autocollimation method, simultaneous equations can be set as follows, for example.
[0025] It is Fi (x1, x2, and x3, ... xn), i= 1, and 2 and 3 about a performance index... It carries out to n:, for example, an image point location. If a real ray trace is used, as shown, for example in drawing 8 , an image point location carries out incidence of the beam of light which extracts from the object point to optical system, and passes along a core, and can be computed as an intersection of the beam of light and the image surface which the beam of light injects. As [show / moreover, / in drawing 9 (a) other than an image point location / what can be treated as a performance index] The center-of-gravity location in the cross section (drawing 9 (b), (c)) where the flux of light (two or more beams of light) injected from optical system has the flux of light (two or more beams of light) which carried out incidence to optical system from the object point, the breadth of the flux of light. Or it is measurable things, such as wave optics-point intensity distribution and a condition of a beam of light, and all can be treated if computable by performing a real ray trace.
[0026] Variable xj (1, 2, 3, ... m), j= 1, 2 and 3, and ... it considers as the eccentricity in the field shown in m:, for example, drawing 10 , or a single lens, and a lens group. Drawing 10 (a) is inclination epsilon[within the inclination epsilon x within the x-z side which shows the definition of the eccentricity of a field and is made with the reference axis of the medial axis of the field on a reference axis, and a y-z side] y. Eccentricity is expressed. Drawing 10 (b) is inclination epsilon[within the inclination epsilon x within the x-z side which shows the definition of the eccentricity of a lens and is made with the medial axis of a lens, and a reference axis, and a y-z side] y. The amount delta x of gaps within the x-z side from the reference axis of the core of the 1st page of a lens, and amount of gaps within y-z side deltay Eccentricity is expressed. Drawing 10 (c) shows the definition of the eccentricity of a lens group, and is the same as that of drawing 10 (b). Drawing 10 (d) is inclination epsilon[within the inclination epsilon x within the x-z side made with the reference axis of the medial axis noting that the definition of the eccentricity of another lens is indicated to be drawing 10 (b) and it is rotating focusing on the point P of arbitration (X, Y), and a y-z side] y. Eccentricity is expressed.
[0027] If the variable value of Fi0 and the first stage is set to xj0 for aij=**Fi/**xj (partial differential) and an early performance-index value here Fi **Fi0+sigmaaij (xj-xj0) ... (2)
It becomes. This Fi What is necessary is just to be able to compute the eccentricity (variable xj) which the image surface location Fim which it is as a result of measurement will be approached enough.
[0028] At Step4, eccentricity (variable) asks for the image point location (performance index Fi0) in an initial state (xj0) by the real ray trace.
[0029] In Step5 to Step7, the matrix Aij which uses aij as a component by difference is searched for. Variation **Fi/**xj [as opposed to / where one eccentricity (variable xi) is changed minutely, perform a real ray trace, and / the unit variation of one eccentricity] of an image point location (performance index Fi) It asks.
[0030] In Step8, it asks for the image point location (performance index Fi) after the variation of eccentricity (variable xi), and change by optimization processing.
[0031] The image point location (performance index Fi) which was able to be found by optimization is compared with the image surface location Fim which it is as a result of measurement, and Step9 estimates whether it is a condition near enough. When it is not in sufficient condition, the image point location after optimization (performance index Fi) and eccentricity (variable xj) are transposed to an initial state (a performance index i0, variable xj0) by Step10, respectively, and it returns to processing of Step5. Processing is ended when [which is in condition sufficient by Step9] it evaluates.
[0032] In the above processing, the reflected light from a test optical system is measured with the conventional autocollimation method. Incidence of the flux of light is carried out from the front of a test optical system, and the image formation location (an image point location or center-of-gravity location) of the reflected light from a measuring plane is measured. The amount of a specimen plane is calculated by making the measured location into a performance index and performing the above processing by making eccentricity of a specimen plane into a variable. In addition to optical system, the eccentricity which was able to be found performs eccentricity calculation processing of the next field as data of optical system. It processes the 1st page at a time in order on the rear face from the front face. If the processing is illustrated, it will become like drawing 5.
[0033] Moreover, with an autocollimation method, one or more the image point location which can be treated as a performance index, center-of-gravity locations of the flux of light, breadth of the flux of light, conditions of a beam of light, etc. are measured as an option, and there is also the approach of making it into a performance index. It is possible to compute at once the eccentricity of one or more specimen planes made into the variable, a single lens, and a group lens by making into a variable at coincidence eccentricity of one or more specimen planes of the range along which light passed at the time of measurement, a single lens, and a group lens, and performing optimization processing.
[0034] Moreover, the amount of local paraxials can also be used instead of the amount of paraxials used with the conventional autocollimation method. The amount [/ near the criteria beam of light in the unsymmetrical optical system in consideration of eccentricity] of local paraxials is obtained by setting up the criteria beam of light of the arbitration from the light source 52 in drawing 7 to the image surface 54, and calculating the breadth of the minute flux of light which spreads near the criteria beam of light over the whole system. There are an image formation location, image formation bearing, focal-line bearing, a scale factor, a focal distance, a pupil location, a principal point location, a joint location, astigmatism, image surface distortion, an illuminance, etc. in the information acquired as an amount of local paraxials (JP,11-287947,A), and the precision of the eccentricity of a test optical system can be improved by adopting the scale factor of the amount of local paraxials instead of being beta of a formula (1).
[0035] Moreover, radius of curvature r, Spacing d, a refractive index n, etc. of an actual field of the optical system which performs the above-mentioned real ray trace may differ from the optical system meant according to the manufacture error etc. The data of the optical system which performs a real ray traced are permuted by data, such as the radius of curvature r of the field measured in the optical element measurement machine 9 grade of drawing 2 , Spacing d, and a refractive index n. Or data, such as the amounts of tolerance, such as manufacture error data, such as the radius of curvature r measured in the optical element measurement machine 9 grade of drawing 2 , Spacing d, and a refractive index n, or radius of curvature r, Spacing d, and a refractive index n, are added to radius of curvature r, Spacing d, a refractive index n, etc. of a field of optical system. This is treated as data of optical system, an actually more near trace result is computed by performing a real ray trace, and the precision of the eccentricity calculated can be improved.

[0036] Moreover, in an autocollimation method, incidence of the flux of light is carried out so that it may converge on the ball center location of a measuring plane-ed. In order to realize this, it may be necessary to measure by moving the interior of measurement machine optical system according to a measuring plane-ed. The amount of fluctuation inside the measurement machine optical system according to a measuring plane-ed is measured and applied to the optical system which performs the above-mentioned real ray trace. By treating this as optical-system data and performing a real ray trace, an actually more near trace result is computed and the precision of the eccentricity calculated can be improved.
[0037] Moreover, there are zoom lenses, such as a camera, an endoscope, and a microscope, etc. in the optical system which performs the above-mentioned eccentric measurement, evaluation, and analysis using a real ray trace.
[0038] Next, the example which performs optical system or eccentric measurement of an optical element, evaluation, and analysis using a real ray trace is shown in drawing 11 and drawing 13 .
[0039] Drawing 11 is drawing showing the example which applied the real ray trace to the aspheric surface eccentricity measurement machine using the oblique incidence method shown in JP,7-120218,A and JP,9-222380,A, and raised precision. The condition that the condition and drawing 11 R> 1 (b) to which drawing 11 (a) made the incidence of the flux of light carry out near the optical axis of the aspheric surface 120 made the incidence of the flux of light carry out aslant to the periphery of the aspheric surface 120 is shown. The flux of light reflected on the front face of the aspheric surface 120 progresses with a mirror 111, the projection lens 103, a beam splitter 115, the microscope objective lens 105, the triangular prism 134, and a zoom lens 106, and in any case, the luminescent spot comes and it carries out image formation to CCD camera 107. Although the luminescent spot of the flux of light which has reflected on CCD camera 107 will draw a curve and will turn around it on CCD camera 107 if the aspheric surface 120 is rotated, it can incline with eccentric deltar of the aspheric surface 120 of a tested aspherical lens 121 in analyzing the locus of this luminescent spot, and can ask for epsilonr with that azimuth epsilontheta and deltatheta.
[0040] However, in an above-mentioned patent of two affairs, since paraxial count and the paraxial count based on local curvature were used for analyzing a locus, it was not necessarily able to be said that it was accurate.
[0041] So, at this invention, it is the optical design data of all the fields of the optical system of the eccentric measurement machine 141, i.e., r:radius of curvature of each field, (in the case of the aspheric surface, it is the equation of a field).
d: Distance n to the next field : input the refractive index of a medium into the computer 150, and calculate the optimum value of epsilonr, deltar and epsilontheta whose locus of the luminescent spot which carried out the real ray trace to the locus when rotating the tested aspherical lens 121 observed with CCD camera 107 by making azimuth epsilontheta of epsilonr and deltar and deltatheta into a variable at epsilonr of a tested aspherical surface and deltar list corresponds, and deltatheta.
[0042] If it does in this way, it can do [asking for epsilonr, deltar, epsilontheta, and deltatheta with a precision more sufficient than the analysis in a paraxial ray, or].
[0043] In addition, the sign 149 in drawing is a digital disposal circuit which processes the output of CCD camera 107, and a sign 151 is TV monitor.
[0044] epsilonx =epsilon r-cosepsilonthetaepsilony =epsilon r-sinepsilonthetadeltax =delta r-cosdeltathetadeltay since it is =delta r-sindeltatheta -- instead of [of epsilonr, deltar, epsilontheta, and deltatheta] -- the component epsilon x of eccentricity, epsilony, delta x, and deltay You may ask.
[0045] The definition of the above-mentioned epsilonr, deltar, epsilontheta, and deltatheta is shown in drawing 12 .
[0046] Next, drawing 13 is drawing showing the example of the centering microscope 160 which used the real ray trace, and this centering microscope 160 is used when joining investigating the eccentricity of each lens for eccentric measurement of one lens, the eccentric measurement of the 1st page of a lens, and junction of two or more lenses.
[0047] the light which came out of the light source 161 in this centering microscope 160 -- the pinhole 162 of a target, the lighting lens 163, and a beam splitter (half prism) 115 -- a passage -- un--- incidence is carried out to **** 164. The flux of light reflected by non-**** 164 progresses with the optical system 102 which has a beam splitter (half prism) 115 and the variable power system 171, a half mirror 167, and the image formation lens 166, serves as the luminescent spot and carries out image formation to CCD camera 107. When rotating a tested lens 165, it can ask for the eccentricity of non-**** 164 from the location or locus of the luminescent spot on CCD camera 107. Instead of CCD camera 107, from the location or locus of the luminescent spot on a reticle 168, it may observe by the eye 170 through an ocular 169, and you may ask for the eccentricity of non-**** 164.
[0048] Here, the image with the lighting lens 163 of a pinhole 162 may not be made into the ball center of non-**** 164, but it may be made in the location from which it separated from the ball center, and drawing 1313 is illustrating such a case. It is called condition of inequality twice image formation. Similarly, it can ask for the eccentricity of the fields 172, 173, and 174 of the lower part of non-**** 164.
[0049] In order to have asked for specimen plane ****** from the location or locus of the luminescent spot, it was analyzing in the paraxial theory conventionally. However, it was a little inaccurate because of the aberration (especially distortion aberration) of the optical system of the centering microscope 160. So, at this invention, it is r:radius of curvature (in the case of the aspheric surface, it is the equation of a field) of each field of the optical system of the centering microscope 160.
d: Distance n to the next field : the refractive index of a medium is inputted into the computer 150, and the eccentricity of non-**** 164 can be known by asking for the eccentricity of non-**** 164 in which the location of the luminescent spot which carried out the real ray trace to the location or locus of the luminescent spot on CCD camera 107 carries out abbreviation coincidence.
[0050] Next, the example of eccentric measurement in case the lens side which consisted of the aspheric surfaces is included in the lens system which has two or more pages is shown. The parameter with which the aspheric surface shifts from inclination epsilon of a lens side since the aspheric surface shaft decided uniquely exists, and the eccentricity of an amount delta is expressed is needed. The parameter showing eccentricity may be expressed with the component (epsilon x and epsilony) of the 2-way with which intersect perpendicularly with an optical axis and a 2-way and each cross at right angles, and (delta x and deltay). Moreover, as the definition of the eccentricity of the aspheric surface is shown in drawing 12 , a polar coordinate (epsilonr, epsilontheta) etc. is sufficient (deltar, deltatheta). What is necessary is just to make it be the following in quest of the parameter showing such eccentricity.
[0051] Since the optical intensity distribution of the reflected image of an index in case it inclines to this field and there is epsilon generally differ from the optical intensity distribution of the reflected image of an index in case it shifts to this field and there is an amount delta when the lens side which it is going to measure is the aspheric surface, It can shift from inclination epsilon of a measuring plane-ed by making the optical intensity distribution of the reflected image of the measured index into

desired value. for example, an amount delta can be made into a variable, a real ray trace or a paraxial-ray trace can be performed, and it can ask for the parameter showing eccentricity by inclining, shifting from epsilon and optimizing an amount delta.

[0052] The above-mentioned optical intensity distribution mean the configuration of the luminous-intensity distribution detected with the detector, and the luminous-intensity distribution calculated geometrical optics-wise or in wave optics.

[0053] Moreover, what is necessary is just to ask for at least one parameter needed in the parameter showing eccentricity, in order to evaluate a test optical system.

[0054] Moreover, in drawing 7 , incidence only of some beams of light is carried out to a test optical system in the flux of light injected from the light source 52. Change variously the include angle of this beam of light and optical axis to make, and the location of the beam of light reflected from a specimen plane to each include angle is detected. A real ray trace or a paraxial-ray trace can be performed to each condition, and it can ask for the parameter showing eccentricity also by inclining, shifting from epsilon and optimizing an amount delta so that the difference of the location of the beam of light measured in all conditions and the beam-of-light location for which it asked with ray tracing may become small.

[0055] Moreover, as shown in drawing 14 , point light source **** is made from the micro-lens array 62. An image sensor 65 detects the light which projected it on the specimen plane 61 with the projection lens 63, and was reflected or refracted by the specimen plane 61 through a half mirror 64 (when making it reflect by the specimen plane 61). Obtain the image of each point light source which is illustrated to drawing 15 , and a real ray trace or a paraxial-ray trace is performed for the purpose of the location of each point light source image. It can ask for the parameter showing eccentricity also by inclining, shifting from epsilon and optimizing an amount delta so that the difference of the location of the point light source image measured in all conditions and the location of the point light source image for which it asked with ray tracing may become small.

[0056] As shown in drawing 16 , moreover, as an application of the Shack-Hartmann method Lead the light which penetrated an analyzed light study component or optical system 71 to the micro-lens array 73 through a collimate lens 72, and a point group is made. An image sensor 75 detects the point group through a relay lens 74, and a real ray trace or a paraxial-ray trace is performed for the purpose of the location of each point image. It can ask for the parameter showing eccentricity also by shifting from inclination epsilon of each field and optimizing an amount delta so that the difference of the location of the point light source image measured in all conditions and the location of the point light source image for which it asked with ray tracing may become small.

[0057] Moreover, it sets to a lens simple substance including the aspheric surface which it is going to measure, and is eccentricity between fields epsilonL between the front face of a lens, and a rear face. When obtained with the eccentricity measurement machine between fields etc. It inclines to the optical axis of the shaft in a front face and a rear-face simple substance, and shifts from epsilon (respectively epsilon 1 and epsilon 2). An amount delta (respectively delta 1 and delta 2) an index -- a reflected image -- measurement -- from -- obtaining -- having had -- a front face -- an inclination -- an amount -- epsilon -- one -- ' -- a rear face -- an inclination -- an amount -- epsilon -- two -- ' -- and -- epsilon -- L -- and -- a front face -- paraxial -- radius of curvature -- R -- one -- a rear face -- paraxial -- radius of curvature -- R -- two -- a lens -- thickness -- T -- from -- a front face -- a rear face -- an inclination -- epsilon -- shifting -- an amount delta -- as follows -- being calculable . in addition -- eccentricity -- expressing -- a parameter -- epsilon -- one -- epsilon -- two -- epsilon -- one -- ' -- epsilon -- two -- ' -- epsilon -- L -- delta -- one -- delta -- two x and y -- each component is expressed.

[0058]
epsilon1'=epsilon1+delta1 / R1 ... (3)
epsilon2'=epsilon2+delta2 / R2 ... (4)
epsilon2 =epsilon1+epsilonL ... (5)
delta2 =delta1+Tepsilon1 ... (6)
Formula (3) From - (6) delta1 =(R1 R2+R1 T) epsilon1'/(R2-R1+T)
- R1 R2/(epsilon2' - epsilonL) (R2-R1+T) ... (7)
delta2 =R1 R2 epsilon1'/(R2-R1+T)
- R1 R2-R2 T(epsilon2' - epsilonL)/(R2-R1+T)
... (8)
epsilon1 =-R1 epsilon1'/(R2-R1+T)
+ R2/(epsilon2' - epsilonL) (R2-R1+T) ... (9)
epsilon2 =epsilon1'+epsilonL ... (10)

It is count based on the paraxial-property of optical system, the above count can calculate eccentricity with the equation of equation (7) - (10), and when calculating the eccentricity of each field of a test optical system by the real ray trace, it can also calculate the eccentricity between fields of both sides of a lens including the aspheric surface as restraint conditions.

[0059] In addition, needless to say, even if it uses mathematically an equivalent equation (for example, thing changed into the polar coordinate) with equation (7) - (10), it is easy to be natural.

[0060] By the way, when measurement of each side of the lens system which has two or more pages is performed using an autocollimation method (drawing 7), In the location of the image of the center of curvature on the appearance of the field 51 which it is going to measure, i.e., the center of curvature of the measuring plane 51-ed by which image formation is carried out in another field which exists between the measuring plane 51-ed and an observation system When producing the same location as the projection location of the index or a light source image, a twice as many reflected image, such as projecting an index or a light source image and being based on a specimen plane 51, as this It is possible that the index image or light source image reflected from other than the lens side which it is going to measure arises near the index by the lens side 51 which it is going to measure, or the light source image. In this case, distinction of the index image by the lens side which which tends to measure, or a light source image is difficult.

[0061] Then, an index or a light source image is projected on the location shifted in the direction which met the optical axis from the location of the image of the center of curvature on the appearance of the field which it is going to measure in such a case, i.e., the center of curvature of the measuring plane 51-ed by which image formation is carried out in another field which exists between the measuring plane 51-ed and an observation system. The situation is shown in drawing 17 . It corresponds, when the light source 52 of drawing 7 or the location of a collimator lens 53 is able to be shifted in accordance with an optical axis. At this time, the locations of that reflected image with the location which projected the index or the light source image differ, and a scale factor is also no longer actual size.

[0062] Moreover, the location of the image of the index reflected from other than the above-mentioned lens side 51 which it is

going to measure, or a light source image also shifts. Since the amount of gaps of the location of the reflected image by the lens side 51 which it is generally going to measure differs from the amount of location gaps of the reflected image from other than the lens side which it is going to measure. By detecting the reflected image of the image of the index by which calculates the amount of gaps of the image of the index reflected, or a light source image by count from the lens side 51 which it is going to measure, and image formation is carried out to this location, or a light source image The index image or light source image by the lens side 51 which it is going to measure is distinguishable. Moreover, the eccentric accuracy of measurement can be raised rather than the case where image formation is carried out by actual size, by making the absolute value of the scale factor of the reflected image of the index to project, the index to a light source image, or a light source image larger than 1. Moreover, the approach of detecting the beam of light refracted by the specimen plane instead of the beam of light reflected by the specimen plane may be used.

[0063] Next, the example which performs refractive-index distribution measurement, evaluation, and analysis of an optical element using a real ray trace is explained using drawing 18 R> 8.

[0064] The laser light from the helium-Ne laser 81 is divided into two optical paths by the beam splitter 82, incidence of one side is carried out to the analyzed light study component 83, it remains, while incidence is carried out to the criteria optical system 84 with the optical-character ability as the design value of the analyzed light study component 83, and the flux of light which penetrated both optical system is compounded by the beam splitter 85, and it projects so that an interference fringe may occur on a screen 86. The image of an interference fringe is incorporated with a television camera, it inputs into a computer, stripes are analyzed, and the phase contrast distribution within the flux of light on a screen 86 is searched for.

[0065] The phase contrast distribution measured by such equipment corresponds to the wave aberration in the exit pupil side at the time of carrying out incidence of the parallel flux of light to the analyzed light study component 83.

[0066] general — refractive-index distribution n(r) =n0+n2 r2+n4 r4+n6 r6+ .. ... (11)
It can be expressed with a ** form.

[0067] It is the multiplier n2 of a formula (11), n4, and n6 so that the wave aberration calculated by the real ray trace may become equal to the measured wave aberration, when thickness of the direction of an optical axis of the analyzed light study component 83 cannot disregard crookedness of the beam of light within the analyzed light study component 83 small enough. It considers as a variable and refractive-index distribution is optimized.

[0068] In this case, if so small that it is thought that gap from the injection wave front at the time of carrying out incidence of the parallel light to the criteria optical system 84 of the injection wave front at the time of carrying out incidence of the parallel light to the analyzed light study component 83 is measured and the aberration of the criteria optical system 84 can be disregarded The gap from the injection wave front at the time of carrying out incidence of the parallel light to the criteria optical system 84 of the injection wave front at the time of carrying out incidence of the parallel light to the analyzed light study component 83, since a injection wave front turns into the spherical surface is in agreement with the wave aberration at the time of carrying out incidence of the parallel light to the analyzed light study component 83.

[0069] Therefore, as a variable which makes an initial state a design value for each refractive-index distribution factor of the medium which defined the refractive-index distribution configuration by the formula (11), a real ray traced is performed, and if it optimizes so that fitting of the injection wave front, i.e., the wave aberration, may be carried out to measured value, each multiplier will be obtained.

[0070] The optical element of the above this invention or the eccentric measuring method of optical system can be constituted as follows.

[0071] [1] The eccentric measuring method, the measurement machine, or the measured thing of the optical element which carries out incidence of the light to a measuring beam-ed study component or optical system, and is characterized by calculating the eccentricity of said optical element or optical system by measuring the condition of the light injected from the optical element or optical system, and using a real ray trace from the measured value, or optical system.

[0072] [2] The eccentric measuring method, the measurement machine, or the measured thing of the optical element which carries out incidence of the beam of light to a measuring beam-ed study component or optical system, and is characterized by calculating the eccentricity of said optical element or optical system by measuring the condition of a beam of light of being injected from the optical element or optical system, and using a real ray trace from the measured value, or optical system.

[0073] [3] The eccentric measuring method, the measurement machine, or the measured thing of the optical element which carries out incidence of the flux of light to a measuring beam-ed study component or optical system, and is characterized by calculating the eccentricity of said optical element or optical system by measuring the condition of the flux of light of being injected from the optical element or optical system, and using a real ray trace from the measured value, or optical system.

[0074] [4] A means to carry out incidence of the light to the specimen plane in an analyzed light study component or optical system, A photodetection means to detect the light in which the light was reflected or refracted from the specimen plane in an analyzed light study component or optical system, In the eccentric measurement machine which measures the eccentricity of each side of the optical element which consists of the optical elements or optical system which lead the light reflected or refracted by said specimen plane to said photodetection means, or optical system From the measuring plane-ed in said optical element or optical system, based on the design value or measured value of the optical element to said photodetection means, or all the optical elements of optical system The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by calculating the eccentricity of a specimen plane to which ray tracing is calculated and the condition of the light in said photodetection means becomes equal to the condition of the measured light by count, or optical system.

[0075] [5] A means to carry out incidence of the beam of light to the specimen plane in an analyzed light study component or optical system, A beam-of-light detection means to detect the beam of light with which the beam of light was reflected or refracted from the specimen plane in an analyzed light study component or optical system, In the eccentric measurement machine which measures the eccentricity of each side of the optical element which consists of the optical elements or optical system which lead the beam of light reflected or refracted by said specimen plane to said beam-of-light detection means, or optical system From the measuring plane-ed in said optical element or optical system, based on the design value or measured value of the optical element to said beam-of-light detection means, or all the optical elements of optical system The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by calculating the eccentricity of a specimen plane to which ray tracing is calculated and the condition of the beam of light in said beam-of-light detection means becomes equal to the condition of the measured beam of light by count, or optical system.

[0076] [6] A means to carry out incidence of the flux of light to the specimen plane in an analyzed light study component or

optical system. A flux of light detection means to detect the flux of light in which the flux of light was reflected or refracted from the specimen plane in an analyzed light study component or optical system. In the eccentric measurement machine which measures the eccentricity of each side of the optical element which consists of the optical elements or optical system which lead the flux of light reflected or refracted by said specimen plane to said flux of light detection means, or optical system From the measuring plane-ed in said optical element or optical system, based on the design value or measured value of the optical element to said flux of light detection means, or all the optical elements of optical system The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by calculating the eccentricity of a specimen plane to which ray tracing is calculated and the condition of the flux of light in said flux of light detection means becomes equal to the condition of the measured flux of light by count, or optical system.
[0077] [7] The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by performing a real ray trace by an optical element or optical system including the optical element of a measuring beam-ed study component, optical system, or a measurement machine, or the manufacture error of optical system, or optical system.
[0078] [8] The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by performing a real ray trace by the optical element or optical system which measured the optical element of a measurement machine, or the amount of fluctuation inside optical system, and took the amount of fluctuation into consideration, or optical system.
[0079] [9] The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by performing a real ray trace by the optical element or optical system containing the eccentricity which measured the 1st page at a time from the optical element or the front face of optical system, calculated eccentricity, and was before calculated in respect of the degree, and calculating the eccentricity of the field, or optical system.
[0080] [10] The eccentric measuring method, the measurement machine, or the measured thing of the optical element of three given in any 1 term from the above 1 characterized by performing solution method processing of the equation which made the unknown desired value and eccentricity of the field to search for for said measured value using a real ray trace, or optical system.
[0081] [11] The eccentric measuring method, the measurement machine, or the measured thing of the optical element of three given in any 1 term from the above 1 characterized by performing solution method processing of the equation which made the unknown two or more fields [measured value / said] on the basis of the location of desired value and arbitration, or the shaft of arbitration, or eccentricity of a lens group using a real ray trace, or optical system.
[0082] [12] The eccentric measuring method, the measurement machine, or the measured thing of an optical element the above 10 characterized by using optimization processing for calculation of said unknown, or given in 11, or optical system.
[0083] [13] The eccentric measuring method, the measurement machine, or the measured thing of the optical element of 12 above-mentioned publication characterized by making wave optics-point intensity distribution into a performance index, or optical system.
[0084] [14] The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by the image formation relation in the case of measuring the image of the flux of light using any of actual size image formation or inequality twice image formation they are, or optical system.
[0085] [15] autocollimation-method [using the amount of local paraxials], or inequality twice -- the optical element characterized by calculating eccentricity by the period of the imitative law after the Buddha's decease, the eccentric measuring method of optical system, a measurement machine, or the measured thing.
[0086] [16] The eccentric measuring method, the measurement machine, or the measured thing of the optical element which makes a variable eccentricity of the measuring plane-ed which is the aspheric surface by making the measured optical intensity distribution or the location of a reflected image of an index into desired value, and is characterized by calculating at least one eccentricity by performing ray tracing and optimizing eccentricity, or optical system.
[0087] [17] The eccentric measuring method, the measurement machine, or the measured thing of the optical element which makes a variable the inclination and the amount of biases of a measuring plane-ed which are the aspheric surface by making the measured optical intensity distribution or the location of an opposite image of an index into desired value, and is characterized by to ask for the parameter with which at least one eccentricity is expressed in each element of an inclination and the amount of biases by performing ray tracing and optimizing an inclination and the amount of biases, or optical system.
[0088] [18] Make the measured optical intensity distribution or the location of a reflected image of an index into desired value. By optimizing the inclination and the amount of biases of the 2-way with which make into a variable the inclination and the amount of biases of a 2-way with which intersect perpendicularly with the optical axis of the measuring plane-ed which is the aspheric surface, and the amount and each cross at right angles, perform ray tracing, and intersect perpendicularly with an optical axis, and a 2-way and each cross at right angles The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for the parameter showing at least one eccentricity of the inclination of a 2-way, and the amount of biases with which intersect perpendicularly with an optical axis and eccentricity and each cross at right angles, or optical system.
[0089] [19] Carry out incidence of the beam of light to a measuring beam-ed study component or optical system, and change variously the include angle of this beam of light and optical axis to make. By optimizing eccentricity so that the difference of the location of the beam of light which detected the location of the beam of light reflected or refracted from a specimen plane to each include angle, and was measured in all conditions, and the beam-of-light location for which it asked with ray tracing may become small The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by calculating at least one eccentricity, or optical system.
[0090] [20] Carry out incidence of the beam of light to a measuring beam-ed study component or optical system, and change variously the include angle of this beam of light and optical axis to make. By optimizing an inclination and the amount of biases so that the difference of the location of the beam of light which detected the location of the beam of light reflected or refracted from a specimen plane to each include angle, and was measured in all conditions, and the beam-of-light location for which it asked with ray tracing may become small The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for the parameter showing at least one eccentricity of an inclination and the amount of biases, or optical system.
[0091] [21] Carry out incidence of the beam of light to a measuring beam-ed study component or optical system, and change variously the include angle of this beam of light and optical axis to make. So that the location of the beam of light reflected or

refracted from a specimen plane to each include angle may be detected and the difference of the location of the beam of light measured in all conditions and the beam-of-light location for which it asked with ray tracing may become small By optimizing the inclination and the amount of biases of the 2-way with which intersect perpendicularly with an optical axis and a 2-way and each cross at right angles The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for the parameter showing at least one eccentricity of the inclination of a 2-way, and the amount of biases with which intersect perpendicularly with an optical axis and eccentricity and each cross at right angles, or optical system.

[0092] [22] the inside of optical system, or the aspheric lens of a simple substance — setting — known eccentricity between fields epsilonL between the front face of a lens, and a rear face It uses, amount of inclinations epsilon1' of the front face obtained from measurement of the reflected image of an index, and the amount epsilon 2 of inclinations on the back — ' — And epsilonL and the front paraxial radius of curvature R1, and the paraxial radius of curvature R2 on the back, It is the inclination epsilon 1 of a front face and a rear face by the formula of the equivalent to the formula or mathematics target of the following [thickness / T / lens], epsilon 2 and the amount delta 1 of biases delta 2 The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by calculating, or optical system.
[0093]
delta1 =(R1 R2+R1 T) epsilon1'/(R2-R1+T)
- R1 R2/(epsilon2' - epsilonL) (R2-R1+T) ... (7)
delta2 =R1 R2 epsilon1'/(R2-R1+T)
- R1 R2-R2 T(epsilon2' - epsilonL)/(R2-R1+T)
... (8)
epsilon1 =-R1 epsilon1'/(R2-R1+T)
+ R2/(epsilon2' - epsilonL) (R2-R1+T) ... (9)
epsilon2 =epsilon1'+epsilonL ... (10)
[23] The eccentric measuring method, the measurement machine, or the measured thing of the optical element which makes eccentricity between the field restraint conditions using the known eccentricity between fields between the front face of a lens, and a rear face, and is characterized by asking for the parameter with which eccentricity is expressed using a real ray trace in the inside of optical system, or the spherical surface or the aspheric lens of a simple substance, or optical system.
[0094] [24] the field which it is going to measure — applying — the upper center of curvature — that is An index is projected on the location shifted in the direction which met the optical axis from the location of the image of the center of curvature of the measuring plane-ed by which image formation is carried out in another field which exists between a measuring plane-ed and the observation system of an eccentric measurement machine. The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by detecting the reflected image of the image of the index by which calculates the amount of gaps of the image of the index reflected by count from the lens side which it is going to measure, and image formation is carried out to this location, or optical system.
[0095] [25] The eccentric measuring method, the measurement machine, or the measured thing of the optical element of 24 above-mentioned publication characterized by the absolute value of the scale factor of the reflected image of the index to the index to project making it larger than 1, or optical system.
[0096] [26] The eccentric measuring method, the measurement machine, or the measured thing of an optical element the above 24 characterized by using a real ray trace, or given in 25, or optical system.
[0097] [27] The light source and a means to divide the light from the light source into two or more point light source groups, A means to project said point light source **** near the specimen plane, and a detection means to detect said point light source **** reflected thru/or refracted by said specimen plane, It has a means to lead said point light source **** reflected thru/or refracted by said specimen plane to said detection means. The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for the parameter with which a paraxial-ray trace or a real ray trace is performed based on the location of detected point light source ****, and the eccentricity of said specimen plane is expressed, or optical system.
[0098] [28] The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by to ask for the parameter with which it has a means divide into two or more point light source **** the light which penetrated an optical element or optical system, a detection means detect said point light source ****, and a means lead said point light source **** to said detection means, a paraxial-ray trace or a real ray trace is performed based on the location of detected point light source ****, and the eccentricity of said specimen plane expresses, or optical system.
[0099] [29] The light source and a means to divide the light from the light source into two or more flux of light groups, A means to project said flux of light group near the specimen plane, and a detection means to detect said flux of light group reflected thru/or refracted by said specimen plane, It has a means to lead said flux of light group reflected thru/or refracted by said specimen plane to said detection means. The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for the parameter with which a paraxial-ray trace or a real ray trace is performed based on the location of the detected flux of light group, and the eccentricity of said specimen plane is expressed, or optical system.
[0100] [30] The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by to ask for the parameter with which it has a means divide into two or more flux of light groups the light which penetrated an optical element or optical system, a detection means detect said flux of light group, and a means lead said flux of light group to said detection means, a paraxial-ray trace or a real ray trace perform based on the location of the detected flux of light group, and the eccentricity of said specimen plane expresses, or optical system.
[0101] [31] The eccentric measuring method, the measurement machine, or the measured thing of the optical element of 30 given in any 1 term from the above 1 characterized by being aimed at the optical system of zoom lenses, such as a camera, an endoscope, and a microscope, or optical system.
[0102] [32] The storage characterized by recording the art of 30 given in any 1 term in a machine-readable form from the above 1.
[0103] [33] The eccentric measurement processor characterized by using the art of 30 given in any 1 term from the above 1.
[0104] [34] The eccentric measuring method, the measurement machine, or the measured thing of the optical element characterized by the computer which controls a measurement machine and the computer which performs a real ray trace being the same, or optical system.

[0105] [35] The physical quantity measuring method, the measurement machine, or the measured thing of the optical element which carries out incidence of the light to a measuring beam-ed study component or optical system, and is characterized by calculating the physical quantity of said optical element or optical system by measuring the condition of the light injected from the optical element or optical system, and using a real ray trace from the measured value, or optical system.
[0106] [36] The physical quantity measuring method, the measurement machine, or the measured thing of the optical element which carries out incidence of the beam of light to a measuring beam-ed study component or optical system, and is characterized by calculating the physical quantity of said optical element or optical system by measuring the condition of a beam of light of being injected from the optical element or optical system, and using a real ray trace from the measured value, or optical system.
[0107] [37] The physical quantity measuring method, the measurement machine, or the measured thing of the optical element which carries out incidence of the flux of light to a measuring beam-ed study component or optical system, and is characterized by calculating the physical quantity of said optical element or optical system by measuring the condition of the flux of light of being injected from the optical element or optical system, and using a real ray trace from the measured value, or optical system.
[0108] [38] A means to carry out incidence of the light to the specimen plane in an analyzed light study component or optical system, A photodetection means to detect the light in which the light was reflected or refracted from the specimen plane in an analyzed light study component or optical system, In the physical quantity measurement machine which measures the physical quantity of each side of the optical element which consists of the optical elements or optical system which lead the light reflected or refracted by said specimen plane to said photodetection means, or optical system From the measuring plane-ed in said optical element or optical system, based on the design value or measured value of the optical element to said photodetection means, or all the optical elements of optical system The physical quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by calculating the physical quantity of a specimen plane to which ray tracing is calculated and the condition of the light in said photodetection means becomes equal to the condition of the measured light by count, or optical system.
[0109] [39] A means to carry out incidence of the beam of light to the specimen plane in an analyzed light study component or optical system, A beam-of-light detection means to detect the beam of light with which the beam of light was reflected or refracted from the specimen plane in an analyzed light study component or optical system, In the physical quantity measurement machine which measures the physical quantity of each side of the optical element which consists of the optical elements or optical system which lead the beam of light reflected or refracted by said specimen plane to said beam-of-light detection means, or optical system From the measuring plane-ed in said optical element or optical system, based on the design value or measured value of the optical element to said beam-of-light detection means, or all the optical elements of optical system The physical quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by calculating the physical quantity of a specimen plane to which ray tracing is calculated and the condition of the beam of light in said beam-of-light detection means becomes equal to the condition of the measured beam of light by count, or optical system.
[0110] [40] A means to carry out incidence of the flux of light to the specimen plane in an analyzed light study component or optical system, A flux of light detection means to detect the flux of light in which the flux of light was reflected or refracted from the specimen plane in an analyzed light study component or optical system, In the physical quantity measurement machine which measures the physical quantity of each side of the optical element which consists of the optical elements or optical system which lead the flux of light reflected or refracted by said specimen plane to said flux of light detection means, or optical system From the measuring plane-ed in said optical element or optical system, based on the design value or measured value of the optical element to said flux of light detection means, or all the optical elements of optical system The physical quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by calculating the physical quantity of a specimen plane to which ray tracing is calculated and the condition of the flux of light in said flux of light detection means becomes equal to the condition of the measured flux of light by count, or optical system.
[0111] [41] The physical quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by performing a real ray trace by an optical element or optical system including the optical element of a measuring beam-ed study component, optical system, or a measurement machine, or the manufacture error of optical system, or optical system.
[0112] [42] The physical quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by performing a real ray trace by the optical element or optical system which measured the optical element of a measurement machine, or the amount of fluctuation inside optical system, and took the amount of fluctuation into consideration, or optical system.
[0113] [43] The physical quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by performing a real ray trace by the optical element or optical system containing the physical quantity which measured the 1st page at a time from the optical element or the front face of optical system, calculated physical quantity, and was before calculated in respect of the degree, and calculating the physical quantity of the field, or optical system.
[0114] [44] The physical quantity measuring method, the measurement machine, or the measured thing of the optical element of 37 given in any 1 term from the above 35 characterized by performing solution method processing of the equation which made the unknown desired value and physical quantity of the field to search for for said measured value using a real ray trace, or optical system.
[0115] [45] The physical quantity measuring method, the measurement machine, or the measured thing of the optical element of 37 given in any 1 term from the above 35 characterized by performing solution method processing of the equation which made the unknown two or more fields [measured value / said] on the basis of the location of desired value and arbitration, or the shaft of arbitration, or physical quantity of a lens group using a real ray trace, or optical system.
[0116] [46] The physical quantity measuring method, the measurement machine, or the measured thing of an optical element the above 44 characterized by using optimization processing for calculation of said unknown, or given in 45, or optical system.
[0117] [47] The physical quantity measuring method, the measurement machine, or the measured thing of the optical element of 46 above-mentioned publication characterized by making wave optics-point intensity distribution into a performance index, or optical system.
[0118] [48] The physical quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by the image formation relation in the case of measuring the image of the flux of light using any of actual size image formation or inequality twice image formation they are, or optical system.
[0119] [49] Carry out incidence of the beam of light to a measuring beam-ed study component or optical system, and change

variously the include angle of this beam of light and optical axis to make. By optimizing physical quantity so that the difference of the location of the beam of light which detected the location of the beam of light reflected or refracted from a specimen plane to each include angle, and was measured in all conditions, and the beam-of-light location for which it asked with ray tracing may become small The physical quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by calculating at least one physical quantity, or optical system.
[0120] [50] Carry out incidence of the beam of light to a measuring beam-ed study component or optical system, and change variously the include angle of this beam of light and optical axis to make. By optimizing an inclination and the amount of biases so that the difference of the location of the beam of light which detected the location of the beam of light reflected or refracted from a specimen plane to each include angle, and was measured in all conditions, and the beam-of-light location for which it asked with ray tracing may become small The physical quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for the parameter showing at least one physical quantity of an inclination and the amount of biases, or optical system.
[0121] [51] Carry out incidence of the beam of light to a measuring beam-ed study component or optical system, and change variously the include angle of this beam of light and optical axis to make. So that the location of the beam of light reflected or refracted from a specimen plane to each include angle may be detected and the difference of the location of the beam of light measured in all conditions and the beam-of-light location for which it asked with ray tracing may become small By optimizing the inclination and the amount of biases of the 2-way with which intersect perpendicularly with an optical axis and a 2-way and each cross at right angles The physical quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for the parameter showing at least one physical quantity of the inclination of a 2-way, and the amount of biases with which intersect perpendicularly with an optical axis and physical quantity and each cross at right angles, or optical system.
[0122] [52] the field which it is going to measure — applying — the upper center of curvature — that is An index is projected on the location shifted in the direction which met the optical axis from the location of the image of the center of curvature of the measuring plane-ed by which image formation is carried out in another field which exists between a measuring plane-ed and the observation system of a physical quantity measurement machine. The physical quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by detecting the reflected image of the image of the index by which calculates the amount of gaps of the image of the index reflected by count from the lens side which it is going to measure, and image formation is carried out to this location, or optical system.
[0123] [53] The physical quantity measuring method, the measurement machine, or the measured thing of the optical element of 52 above-mentioned publication characterized by the absolute value of the scale factor of the reflected image of the index to the index to project making it larger than 1, or optical system.
[0124] [54] The physical quantity measuring method, the measurement machine, or the measured thing of an optical element the above 52 characterized by using a real ray trace, or given in 53, or optical system.
[0125] [55] The light source and a means to divide the light from the light source into two or more point light source groups, A means to project said point light source **** near the specimen plane, and a detection means to detect said point light source **** reflected thru/or refracted by said specimen plane, It has a means to lead said point light source **** reflected thru/or refracted by said specimen plane to said detection means. The physical quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for the parameter with which a paraxial-ray trace or a real ray trace is performed based on the location of detected point light source ****, and the physical quantity of said specimen plane is expressed, or optical system.
[0126] [56] The physical-quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by to ask for the parameter with which it has a means divide into two or more point light source **** the light which penetrated an optical element or optical system, a detection means detect said point light source ****, and a means lead said point light source **** to said detection means, a paraxial-ray trace or a real ray trace performs based on the location of detected point light source ****, and the physical quantity of said specimen plane expresses, or optical system.
[0127] [57] The light source and a means to divide the light from the light source into two or more flux of light groups, A means to project said flux of light group near the specimen plane, and a detection means to detect said flux of light group reflected thru/or refracted by said specimen plane, It has a means to lead said flux of light group reflected thru/or refracted by said specimen plane to said detection means. The physical quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for the parameter with which a paraxial-ray trace or a real ray trace is performed based on the location of the detected flux of light group, and the physical quantity of said specimen plane is expressed, or optical system.
[0128] [58] The physical-quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by to ask for the parameter with which it has a means divide into two or more flux of light groups the light which penetrated an optical element or optical system, a detection means detect said flux of light group, and a means lead said flux of light group to said detection means, a paraxial-ray trace or a real ray trace perform based on the location of the detected flux of light group, and the physical quantity of said specimen plane expresses, or optical system.
[0129] [59] The physical quantity measuring method, the measurement machine, or the measured thing of the optical element of 58 given in any 1 term from the above 35 characterized by being aimed at the optical system of zoom lenses, such as a camera, an endoscope, and a microscope, or optical system.
[0130] [60] The physical quantity measurement processor characterized by using the art of 58 given in any 1 term from the above 35.
[0131] [61] The physical quantity measuring method, the measurement machine, or the measured thing of the optical element characterized by the computer which controls a measurement machine and the computer which performs a real ray trace being the same, or optical system.
[0132] [62] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element which carries out incidence of the light to a measuring beam-ed study component or optical system, and is characterized by asking for said optical element or the refractive-index distribution pattern of optical system by measuring the condition of the light injected from the optical element or optical system, and using a real ray trace from the measured value, or optical system.
[0133] [63] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element which carries out incidence of the beam of light to a measuring beam-ed study component or optical system, and

is characterized by asking for said optical element or the refractive-index distribution pattern of optical system by measuring the condition of a beam of light of being injected from the optical element or optical system, and using a real ray trace from the measured value, or optical system.
[0134] [64] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element which carries out incidence of the flux of light to a measuring beam-ed study component or optical system, and is characterized by asking for said optical element or the refractive-index distribution pattern of optical system by measuring the condition of the flux of light of being injected from the optical element or optical system, and using a real ray trace from the measured value, or optical system.
[0135] [65] A means to carry out incidence of the light to the specimen plane in an analyzed light study component or optical system, A photodetection means to detect the light in which the light was reflected or refracted from the specimen plane in an analyzed light study component or optical system, In the refractive-index distribution pattern measurement machine which measures the optical element which consists of the optical elements or optical system which lead the light reflected or refracted by said specimen plane to said photodetection means, or the refractive-index distribution pattern of each side of optical system From the measuring plane-ed in said optical element or optical system, based on the design value or measured value of the optical element to said photodetection means, or all the optical elements of optical system The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for a refractive-index distribution pattern of a specimen plane with which ray tracing is calculated and the condition of the light in said photodetection means becomes equal to the condition of the measured light by count, or optical system.
[0136] [66] A means to carry out incidence of the beam of light to the specimen plane in an analyzed light study component or optical system, A beam-of-light detection means to detect the beam of light with which the beam of light was reflected or refracted from the specimen plane in an analyzed light study component or optical system, In the refractive-index distribution pattern measurement machine which measures the optical element which consists of the optical elements or optical system which lead the beam of light reflected or refracted by said specimen plane to said beam-of-light detection means, or the refractive-index distribution pattern of each side of optical system From the measuring plane-ed in said optical element or optical system, based on the design value or measured value of the optical element to said beam-of-light detection means, or all the optical elements of optical system The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for a refractive-index distribution pattern of a specimen plane with which ray tracing is calculated and the condition of the beam of light in said beam-of-light detection means becomes equal to the condition of the measured beam of light by count, or optical system.
[0137] [67] A means to carry out incidence of the flux of light to the specimen plane in an analyzed light study component or optical system, A flux of light detection means to detect the flux of light in which the flux of light was reflected or refracted from the specimen plane in an analyzed light study component or optical system, In the refractive-index distribution pattern measurement machine which measures the optical element which consists of the optical elements or optical system which lead the flux of light reflected or refracted by said specimen plane to said flux of light detection means, or the refractive-index distribution pattern of each side of optical system From the measuring plane-ed in said optical element or optical system, based on the design value or measured value of the optical element to said flux of light detection means, or all the optical elements of optical system The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for a refractive-index distribution pattern of a specimen plane with which ray tracing is calculated and the condition of the flux of light in said flux of light detection means becomes equal to the condition of the measured flux of light by count, or optical system.
[0138] [68] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by performing a real ray trace by an optical element or optical system including the optical element of a measuring beam-ed study component, optical system, or a measurement machine, or the manufacture error of optical system, or optical system.
[0139] [69] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by performing a real ray trace by the optical element or optical system which measured the optical element of a measurement machine, or the amount of fluctuation inside optical system, and took the amount of fluctuation into consideration, or optical system.
[0140] [70] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by performing a real ray trace by the optical element or optical system containing the refractive-index distribution pattern for which measured the 1st page at a time from the optical element or the front face of optical system, and asked for the refractive-index distribution pattern, and it asked before in respect of the degree, and asking for the refractive-index distribution pattern of the field, or optical system.
[0141] [71] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element of 64 given in any 1 term from the above 62 characterized by performing solution method processing of the equation which made the unknown desired value and the refractive-index distribution pattern of a field for which it asks for said measured value using a real ray trace, or optical system.
[0142] [72] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element of 64 given in any 1 term from the above 62 characterized by performing solution method processing of the equation which made the unknown two or more fields [measured value / said] on the basis of the location of desired value and arbitration, or the shaft of arbitration, or the refractive-index distribution pattern of a lens group using a real ray trace, or optical system.
[0143] [73] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of an optical element the above 71 characterized by using optimization processing for calculation of said unknown, or given in 72, or optical system.
[0144] [74] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element of 73 above-mentioned publication characterized by making wave optics-point intensity distribution into a performance index, or optical system.
[0145] [75] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by the image formation relation in the case of measuring the image of the flux of light using any of actual size image formation or inequality twice image formation they are, or optical system.
[0146] [76] Carry out incidence of the beam of light to a measuring beam-ed study component or optical system, and change

variously the include angle of this beam of light and optical axis to make. By optimizing a refractive-index distribution pattern so that the difference of the location of the beam of light which detected the location of the beam of light reflected or refracted from a specimen plane to each include angle, and was measured in all conditions, and the beam-of-light location for which it asked with ray tracing may become small The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for at least one refractive-index distribution pattern, or optical system.
[0147] [77] Carry out incidence of the beam of light to a measuring beam-ed study component or optical system, and change variously the include angle of this beam of light and optical axis to make. By optimizing an inclination and the amount of biases so that the difference of the location of the beam of light which detected the location of the beam of light reflected or refracted from a specimen plane to each include angle, and was measured in all conditions, and the beam-of-light location for which it asked with ray tracing may become small The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for the parameter showing at least one refractive-index distribution pattern of an inclination and the amount of biases, or optical system.
[0148] [78] Carry out incidence of the beam of light to a measuring beam-ed study component or optical system, and change variously the include angle of this beam of light and optical axis to make. So that the location of the beam of light reflected or refracted from a specimen plane to each include angle may be detected and the difference of the location of the beam of light measured in all conditions and the beam-of-light location for which it asked with ray tracing may become small By optimizing the inclination and the amount of biases of the 2-way with which intersect perpendicularly with an optical axis and a 2-way and each cross at right angles The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for the parameter showing at least one refractive-index distribution pattern of the inclination of a 2-way, and the amount of biases with which it intersects perpendicularly with an optical axis, and each intersects perpendicularly, or optical system.
[0149] [79] the field which it is going to measure -- applying -- the upper center of curvature -- that is An index is projected on the location shifted in the direction which met the optical axis from the location of the image of the center of curvature of the measuring plane-ed by which image formation is carried out in another field which exists between a measuring plane-ed and the observation system of a refractive-index distribution pattern measurement machine. The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by detecting the reflected image of the image of the index by which calculates the amount of gaps of the image of the index reflected by count from the lens side which it is going to measure, and image formation is carried out to this location, or optical system.
[0150] [80] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element of 79 above-mentioned publication characterized by the absolute value of the scale factor of the reflected image of the index to the index to project making it larger than 1, or optical system.
[0151] [81] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of an optical element the above 79 characterized by using a real ray trace, or given in 80, or optical system.
[0152] [82] The light source and a means to divide the light from the light source into two or more point light source groups, A means to project said point light source **** near the specimen plane, and a detection means to detect said point light source **** reflected thru/or refracted by said specimen plane, It has a means to lead said point light source **** reflected thru/or refracted by said specimen plane to said detection means. The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for the parameter with which a paraxial-ray trace or a real ray trace is performed based on the location of detected point light source ****, and the refractive-index distribution pattern of said specimen plane is expressed, or optical system.
[0153] [83] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by to ask for the parameter with which it has a means divide into two or more point light source **** the light which penetrated an optical element or optical system, a detection means detect said point light source ****, and a means lead said point light source **** to said detection means, a paraxial-ray trace or a real ray trace performs based on the location of detected point light source ****, and the refractive-index distribution pattern of said specimen plane expresses, or optical system.
[0154] [84] The light source and a means to divide the light from the light source into two or more flux of light groups, A means to project said flux of light group near the specimen plane, and a detection means to detect said flux of light group reflected thru/or refracted by said specimen plane, It has a means to lead said flux of light group reflected thru/or refracted by said specimen plane to said detection means. The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for the parameter with which a paraxial-ray trace or a real ray trace is performed based on the location of the detected flux of light group, and the refractive-index distribution pattern of said specimen plane is expressed, or optical system.
[0155] [85] A means to divide into two or more flux of light groups the light which penetrated an optical element or optical system, It has a detection means to detect said flux of light group, and a means to lead said flux of light group to said detection means. The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by asking for the parameter with which a paraxial-ray trace or a real ray trace is performed based on the location of the detected flux of light group, and the refractive-index distribution pattern of said specimen plane is expressed, or optical system.
[0156] [86] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element of 85 given in any 1 term from the above 62 characterized by being aimed at the optical system of zoom lenses, such as a camera, an endoscope, and a microscope, or optical system.
[0157] [87] The refractive-index distribution pattern measurement processor characterized by using the art of 85 given in any 1 term from the above 62.
[0158] [88] The refractive-index distribution pattern measuring method, the measurement machine, or the measured thing of the optical element characterized by the computer which controls a measurement machine and the computer which performs a real ray trace being the same, or optical system.
[0159]
[Effect of the Invention] Since physical quantity is calculated by measuring the condition of the light injected from a measuring beam-ed study component or optical system in the optical element of this invention, or the physical quantity measuring method of optical system, and using a real ray trace from the measured value so that clearly from the above explanation, it can ask for

the parameter showing the physical quantity of the optical system which consists of the simple substance or combination of an optical element in a high precision.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is drawing for explaining the real ray trace used by the eccentric measuring method of this invention.
[Drawing 2] It is the block diagram of the processor which enforces the optical element of one example of this invention, or the eccentric measuring method of optical system.
[Drawing 3] It is the flow chart of the processing performed with the equipment of drawing 2 .
[Drawing 4] It is the flow chart which shows the detail of eccentricity calculation processing of drawing 3 .
[Drawing 5] It is the flow chart of the processing which performs the 1st page of eccentricity calculation processing of drawing 4 at a time on a rear face in order from a front face.
[Drawing 6] It is drawing showing an example of the measurement machine for measuring the amount of deflections from the reference axis of a reflected image.
[Drawing 7] It is drawing for explaining signs that the amount of deflections from the reference axis of a reflected image is measured with an autocollimator.
[Drawing 8] It is drawing for explaining an example of the real ray trace for image point location calculation.
[Drawing 9] It is drawing for explaining an example of the real ray trace for the center-of-gravity location of the flux of light, and breadth calculation of the flux of light.
[Drawing 10] They are a lens side, a single lens, and drawing showing the example of a definition of the eccentricity of a lens group.
[Drawing 11] It is drawing showing the example which applied the real ray trace method of this invention in the aspheric surface eccentricity measurement machine using an oblique incidence method.
[Drawing 12] It is drawing showing the definition of eccentricity epsilonr, deltar, epsilontheta, and deltatheta.
[Drawing 13] It is drawing showing the example of the centering microscope using the real ray trace method of this invention.
[Drawing 14] It is drawing showing the arrangement which makes point light source **** from a micro-lens array by this invention, and calculates eccentricity.
[Drawing 15] It is drawing showing the example of the image of each point light source in drawing 14 .

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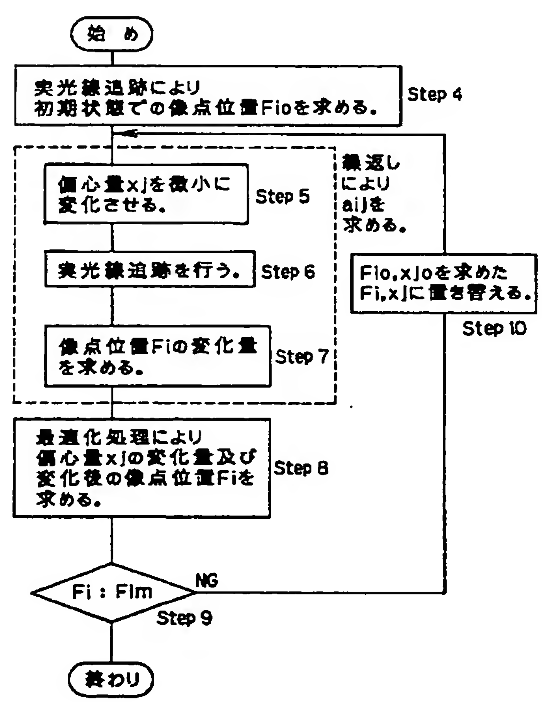
最終頁に続く

(54)【発明の名称】 光学素子又は光学系の物理量測定方法

(57)【要約】

【課題】 光学素子の単体又は組み合わせからなる光学系の偏心を表すパラメータを高い精度で求める手法。

【解決手段】 被測定光学素子又は光学系に光線を入射させ、この光線と光軸とのなす角度をさまざまに変化させ、それぞれの角度に対して被検面からの反射又は屈折する光線の位置を検出し、それぞれの状態に対してリアルレイトレースを行い、全ての状態において測定された光線の位置と光線追跡で求めた光線位置との差が小さくなるように偏心量を最適化することで、少なくとも一つの偏心量を求める偏心測定方法。



【特許請求の範囲】

【請求項１】　被測定光学素子又は光学系に光を入射し、その光学素子又は光学系から射出される光の状態を測定し、その測定値よりリアルレイトレースを用いることにより前記光学素子又は光学系の物理量を求めることを特徴とする光学素子又は光学系の物理量測定方法。

【請求項２】　光束の像を測定する場合の結像関係が等倍結像あるいは不等倍結像の何れかを用いることを特徴とする光学素子又は光学系の物理量測定方法。

【請求項３】　被測定光学素子又は光学系に光線を入射させ、この光線と光軸とのなす角度をさまざまに変化させ、それぞれの角度に対して被検面からの反射又は屈折する光線の位置を検出し、全ての状態において測定された光線の位置と光線追跡で求めた光線位置との差が小さくなるように物理量を最適化することで、少なくとも一つの物理量を求めることを特徴とする光学素子又は光学系の物理量測定方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、光学素子又は光学系の物理量測定方法に関するものである。

【０００２】

【従来の技術】レンズ系の物理量（形状、曲率半径、面間隔、非球面係数、屈折率分布等を含む）の中、従来、一般的なレンズ系の偏心量の測定方法としては、オートコリメーション法が知られている。オートコリメーション法は、測定しようとする面の見かけ上の曲率中心、すなわち、被測定面と観察系との間に存在する別の面によって結像される被測定面の曲率中心の像の位置に指標を投影し、被検面による等倍の反射像をその指標の投影位置と同じ位置に生じさせる方法である。

【０００３】上記の場合において、測定基準軸に関して全てのレンズ面に偏心がなければこの基準軸上に指標像が形成されるが、もし何れかのレンズ面に偏心が存在すれば、基準軸から基準軸に対して垂直な方向に離れた位置に反射像が形成されることになる。この反射像の基準軸からの振れ量Δは個々のレンズ面の偏心量εと関数関係があるので、各レンズ面についてその見かけの球心位置に投影した指標像の等倍反射像の振れ量Δを測定すれば、計算によってその測定基準軸に対する各レンズ面の偏心量を求めることができる。

【０００４】図７は、偏心量（軸の傾き）εを持つ１被測定面５１により生じた振れ量Δを示した概略図である。図７のように、光源（指標）５２からの光束をコリメータレンズ５３で収束させて被測定面５１の測定基準軸上の球心位置に収束するように入射させる。光束の収束位置と被測定面５１の球心位置が一致する場合には、光束は被測定面５１に垂直入射することになる。しかし、光束の収束位置と被測定面５１の球心位置が一致していない（被測定面５１がε偏心している）と、光束は被測定面５１に斜入射することになる。ここで、垂直入射の場合は、被測定面５１で発生した反射光は入射時の光路を逆行し、光源（指標）５２と共役な位置に収束することになる。これに対し斜入射の場合は、被測定面５１で発生する反射光は入射時の光路からずれ、垂直入射した場合に収束した位置からΔずれた位置に収束する。

【０００５】

【発明が解決しようとする課題】しかし、上記従来技術において、像面５４で測定された振れ量Δとレンズ面５１の偏心量εとの関係が比例するものであるとし、この比例関係の比例係数を近軸計算によって求めていたため、計算で得られた偏心量εの精度が低下することがあり得た。図７に示すコリメータレンズ５３の近軸計算により求めた倍率βを使用した場合、振れ量Δと被測定面５１の偏心量εとの関係式は被測定面５１の曲率半径をｒとすると、

$$\Delta = 2\beta r\varepsilon \quad \cdots (1)$$

となる。

【０００６】本発明は従来技術のこのような問題に鑑みてなされたものであり、その目的は、光学素子の単体又は組み合わせからなる光学系の偏心をはじめとする物理量を表すパラメータを高い精度で求める手法を提供することである。

【０００７】

【課題を解決するための手段】上記目的を達成する本発明の光学素子又は光学系の偏心測定方法は、被測定光学素子又は光学系に光を入射し、その光学素子又は光学系から射出される光の状態を測定し、その測定値よりリアルレイトレースを用いることにより前記光学素子又は光学系の偏心量を求めることを特徴とする方法である。

【０００８】本発明のもう一つの光学素子又は光学系の偏心測定方法は、光束の像を測定する場合の結像関係が等倍結像あるいは不等倍結像の何れかを用いることを特徴とする方法である。

【０００９】本発明のさらにもう一つの光学素子又は光学系の偏心測定方法は、被測定光学素子又は光学系に光線を入射させ、この光線と光軸とのなす角度をさまざまに変化させ、それぞれの角度に対して被検面からの反射又は屈折する光線の位置を検出し、全ての状態において測定された光線の位置と光線追跡で求めた光線位置との差が小さくなるように偏心量を最適化することで、少なくとも一つの偏心量を求めることを特徴とする方法である。

【００１０】

【発明の実施の形態】以下、本発明の光学素子又は光学系の偏心測定方法の原理と実施例について説明する。

【００１１】本発明は前記の問題点を解決するために、測定された振れ量Δから面の偏心量を算出する処理にリアルレイトレースを用いるものである。リアルレイトレ

ースは実光線追跡とも呼ばれる。屈折及び反射の法則を厳密に計算して光線の位置、方向等を計算する方法である。光学系の偏心量、非球面を考慮した光線追跡が可能であり、計算機を用いた光学系の設計、評価等に広く利用されている。

【００１２】リアルレイトレースの処理は、図１に示すように、光学系に入射する光線の位置ベクトルP_0、方向ベクトルR_0 からの光学系の第１面（最初に光線と交わる面）との交点P_1 を求め、交点位置での面の法線ベクトルH_1 から光線の入射角θ_{i1}が決まる。入射側の媒質の屈折率n_0 と射出側の屈折率n_1 より、スネルの法則を用いて射出角θ_{01}、射出光線の方向ベクトルR_1 が求まる。第１面の交点の位置ベクトルP_1 、射出光線の方向ベクトルR_1 を第２面（次に光線と交わる面）への入射光線にして、次の面との交点、射出光線を繰り返し求めていくものである。

【００１３】リアルレイトレースにより、光学系に入射した光束あるいは光線が光学系をいかに通り、射出されるかが計算でき、光束あるいは光線の像点位置、光束の重心位置、光束の状態（大きさ、形）、光線の方向・位置、光線の状態（強度、偏光状態）、又は、光束の広がり、ローカル近軸量（特開平１１－２８７９４７号）等の光学系の各種特性を算出することが可能である。

【００１４】前記の発明が解決しようとする課題であげた振れ量Δは、例えば図６に示す光学系からなる測定機により測定される。振れ量Δは像点位置あるいは光束の重心位置を求める処理になる。物点（半導体レーザ）２０１から出た絞り中心を通る光線（主光線）を、測定用光学系２０２、ビームスプリッタ２０４を介して被測定レンズ２０３の各面の曲率中心に対して順々に投射し、この反射光を像面（ＣＣＤカメラ２０７の受光面）まで追跡し、像面（ＣＣＤカメラ２０７の受光面）での座標値を求める。ここでの絞り中心は、被検組上がりレンズ系（被測定レンズ２０３）の絞りの中心に限らず、被検面と光軸又はグローバル座標又はイメージローテータ２０５の回転中心軸との交点等を選んでもよい。また、光束の重心位置、形状は、物点（半導体レーザ）２０１から出た光線を複数本追跡し、光学系（測定用光学系）２０２からの射出光線をそれぞれ求める。射出光線の位置と方向、光線の強度等から像面（ＣＣＤカメラ２０７の受光面）での光束の重心位置、大きさ、形等を求める。

【００１５】光線の強度、偏光状態は、光線の面への入射角、射出角、面の前後の屈折率によりエネルギー透過率、エネルギー反射率が求まり、各面の射出後のエネルギー透過率あるいはエネルギー反射率を掛け合わせることでその光線の強度が求まる。面にコーティング処理が施してある場合は、各層毎の特性行列を用いて透過率、反射率を算出できる。また、偏光状態も上記透過率、反射率を用いてジョーンズベクトルを追跡することで算出できる（「光学の原理」東海大学出版、「結晶光学」応用物理学会光学懇話会、「光学薄膜」共立出版　参照）。

【００１６】以下、本発明の光学素子又は光学系の偏心測定方法の１実施例を説明する。

【００１７】図２に、偏心測定方法を実施する処理装置のブロック図を示す。本装置は、上記のような光束の像の状態又は光線の状態を測定する測定機８、表示装置２、キーボード等の入力装置３、磁気ディスク等の記憶装置４、プリンター等６、及び、それらを統括処理し、かつ、処理を行う演算処理装置１よりなる。この他に、外部の光学素子測定機９、光学系設計装置１０等とデータや処理方法等をやりとりするためのＬＡＮ７に接続されており、フロッピー（登録商標）ディスクや光磁気ディスク等の外部媒体５との入出力機構も備えている。

【００１８】測定機８からは、前記のように、被検光学系から射出される光束の像の状態、又は、光線の状態の測定データの他、測定光学系に関する面間隔データ、移動量等も送られる。

【００１９】光学素子測定機９は、光学素子の面形状、面間隔、媒質の屈折率、コーティング膜厚等の各種測定機の集合であり、この測定機９からは、被検光学系、測定光学系のｒ、ｄ、ｎの測定データ、あるいは、コーティングデータ、製造誤差データ等が送られる。ここで、ｒ：曲率又は曲率半径（非球面の場合は面の方程式）、ｄ：面間隔、ｎ：媒質の屈折率、コーティングデータ：各膜の複素屈折率、膜厚である。

【００２０】光学系設計装置１０は、光学系を設計する装置である。この装置からは、被検光学系、測定光学系のｒ、ｄ、ｎ等の設計値データ等が送られる。また、本発明の方法より求めた偏心データを取り込み、設計に反映し、又は、光学系を評価することが可能となっている。

【００２１】図２の装置で図３に示す処理を行う。すなわち、Ｓｔｅｐ１では、図２の入力装置３、記憶装置４、外部媒体５、測定機８、光学素子測定機９、光学系設計装置１０からのＳｔｅｐ２の偏心量算出処理に用いる被検光学系、測定光学系のｒ、ｄ（測定光学系における測定のための面間隔移動量も含む）、ｎデータ、コーティングデータ、製造誤差データ、被検光学系から射出される光束の像の状態データ、又は、光線の状態の測定データ、既に分かっている偏心データ、求める偏心の種類、範囲等を必要に応じて入力する。

【００２２】Ｓｔｅｐ２では、Ｓｔｅｐ１で入力された各種データを基に、図２の演算装置１によりリアルレイトレースを行い、求める偏心量を算出する。

【００２３】Ｓｔｅｐ３では、求めた偏心量を図２の表示装置２、記憶装置４、外部媒体５、プリンタ６に出力する。又は、測定機８、光学素子測定機９、光学系設計装置１０等にデータ転送する。

【００２４】次に、図３の偏心量算出処理Ｓｔｅｐ２に

相当する部分の処理を、図４の連立方程式の解法にリアルレイトレースを用いた例で説明を行う。従来のオートコリメーション法を用いた偏心測定に当てはめると、連立方程式は例えば以下のようにおける。

【００２５】評価関数をF_i（x_1，x_2，x_3，・・・，x_n）、ｉ＝１，２，３・・・ｎ：例えば像点位置とする。像点位置は、リアルレイトレースを用いれば、例えば図８に示すように、物点から光学系に絞り中心を通る光線を入射させ、その光線が射出する光線と像面との交点として算出できる。また、評価関数として扱えるものは、像点位置のほかに、例えば図９（ａ）に示すような、物点から光学系に入射した光束（複数本の光線）が光学系から射出される光束（複数本の光線）のある断面（図９（ｂ）、（ｃ））における重心位置、光束の広がり、又は、波動光学的点像強度分布、光線の状態等、測定可能なものでリアルレイトレースを行うことにより算出できるものであれば全て扱える。

【００２６】変数x_j（１，２，３，・・・ｍ）、ｊ＝１，２，３，・・・ｍ：例えば図１０に示した面あるいは単レンズ、レンズ群における偏心量とする。図１０（ａ）は、面の偏心量の定義を示しており、基準軸上の面の中心軸の基準軸となすｘ－ｚ面内の傾きε_x、ｙ－ｚ面内の傾きε_yで偏心量を表している。図１０（ｂ）は、レンズの偏心量の定義を示しており、レンズの中心軸と基準軸となすｘ－ｚ面内の傾きε_x、ｙ－ｚ面内の傾きε_yと、レンズ第１面の中心の基準軸からのｘ－ｚ面内のズレ量δ_x、ｙ－ｚ面内のズレ量δ_yとで偏心量を表している。図１０（ｃ）は、レンズ群の偏心量の定義を示しており、図１０（ｂ）と同様である。図１０（ｄ）は、図１０（ｂ）とは別のレンズの偏心量の定義を示しており、任意の点Ｐ（Ｘ，Ｙ）を中心に回転しているとして、その中心軸の基準軸となすｘ－ｚ面内の傾きε_x、ｙ－ｚ面内の傾きε_yで偏心量を表している。

【００２７】ここで、$a_{ij}=\partial F_i/\partial x_j$（偏微分）、初期の評価関数値を$F_{i0}$、初期の変数値を$x_{j0}$とすると、

$$F_i \fallingdotseq F_{i0}+\Sigma a_{ij}(x_j - x_{j0}) \quad \cdots (2)$$

となる。このF_iが測定結果である像面位置F_{im}に十分近づいた状態になる偏心量（変数x_j）が算出できればよい。

【００２８】Ｓｔｅｐ４では、偏心量（変数）が初期状態（x_{j0}）での像点位置（評価関数F_{i0}）をリアルレイトレースで求める。

【００２９】Ｓｔｅｐ５からＳｔｅｐ７では、差分によりa_{ij}を成分とする行列A_{ij}を求める。一つの偏心量（変数x_j）を微小に変化させた状態でリアルレイトレースを行い、一つの偏心量の単位変化量に対する像点位置（評価関数F_i）の変化量$\partial F_i/\partial x_j$を求める。

【００３０】Ｓｔｅｐ８では、最適化処理により偏心量（変数x_j）の変化量と変化後の像点位置（評価関数F_i）を求める。

【００３１】Ｓｔｅｐ９では、最適化により求まった像点位置（評価関数F_i）と測定結果である像面位置F_{im}を比較し、十分に近い状態かどうか評価する。もし、十分な状態でない場合、Ｓｔｅｐ１０で最適化後の像点位置（評価関数F_i）、偏心量（変数x_j）をそれぞれ初期状態（評価関数${}_{i0}$、変数x_{j0}）に置き換えて、Ｓｔｅｐ５の処理に戻る。Ｓｔｅｐ９で十分な状態である評価した場合は、処理を終了する。

【００３２】以上の処理において、従来のオートコリメーション法では、被検光学系からの反射光を測定する。被検光学系の前方から光束を入射し、測定面からの反射光の結像位置（像点位置又は重心位置）を測定する。測定した位置を評価関数とし、被検面の偏心量を変数として、以上の処理を行うことにより、被検面の量を求める。求まった偏心量は光学系に加え、光学系のデータとして次の面の偏心量算出処理を行う。前面から後面に１面ずつ順に処理を行っていく。その処理を図示すると図５のようになる。

【００３３】また、オートコリメーション法とは別の方法として、評価関数として扱える像点位置、光束の重心位置、光束の広がり、光線の状態等を一つあるいは複数測定し、評価関数とする方法もある。測定時に光が通った範囲の一つ以上の被検面、単レンズ、群レンズの偏心量を同時に変数にして最適化処理を行うことにより、変数にした一つ以上の被検面、単レンズ、群レンズの偏心量を一度に算出することが可能である。

【００３４】また、従来のオートコリメーション法で用いている近軸量の代わりに、ローカル近軸量を用いることもできる。図７における光源５２から像面５４に至る任意の基準光線を設定し、基準光線の近傍を伝播する微小光束の広がりを全系にわたって計算することにより、偏心量を考慮した非対称光学系での基準光線近傍におけるローカル近軸量が得られる。ローカル近軸量として得られる情報には、結像位置、結像方位、焦線方位、倍率、焦点距離、瞳位置、主点位置、節点位置、非点収差、像面歪曲、照度等があり（特開平１１－２８７９４７号）、式（１）のβの代わりにローカル近軸量の倍率を採用することにより、被検光学系の偏心量の精度を向上することができる。

【００３５】また、上記リアルレイトレースを行う光学系の実際の面の曲率半径ｒ、面間隔ｄ、屈折率ｎ等は製造誤差等により意図した光学系とは異なるものになっていることもある。リアルレイトレースを行う光学系のデータを、図２の光学素子測定機９等で測定された面の曲率半径ｒ、面間隔ｄ、屈折率ｎ等のデータと置換、又は、図２の光学素子測定機９等で測定された曲率半径ｒ、面間隔ｄ、屈折率ｎ等の製造誤差データ、又は、曲率半径ｒ、面間隔ｄ、屈折率ｎ等の公差量等のデータ

を、光学系の面の曲率半径ｒ、面間隔ｄ、屈折率ｎ等に加える。これを光学系のデータとして扱い、リアルレイトレースを行うことで、実際により近い追跡結果が算出され、求められる偏心量の精度を向上することができる。

【００３６】また、オートコリメーション法では、被測定面の球心位置に収束するように光束を入射させる。これを実現するためには、被測定面に応じて測定機光学系内部を動かして測定を行う必要がある場合もある。上記リアルレイトレースを行う光学系に、被測定面に応じた測定機光学系内部の変動量を測定して加える。これを光学系データとして扱い、リアルレイトレースを行うことにより、実際により近い追跡結果が算出され、求められる偏心量の精度を向上することができる。

【００３７】また、リアルレイトレースを用いて上記偏心測定、評価、解析を行う光学系には、カメラ、内視鏡、顕微鏡等のズームレンズ等がある。

【００３８】次に、リアルレイトレースを用いて光学系あるいは光学素子の偏心測定、評価、解析を行う実施例を図１１と図１３に示す。

【００３９】図１１は、特開平７－１２０２１８号及び特開平９－２２２３８０号に示されている斜入射法を用いた非球面偏心測定機にリアルレイトレースを応用し、精度を向上させた例を示す図である。図１１（ａ）は、非球面１２０の光軸付近に光束を入射させた状態、図１１（ｂ）は、非球面１２０の周辺部に光束を斜めに入射させた状態を示している。何れの場合も、非球面１２０の表面で反射した光束は、ミラー１１１、投影レンズ１０３、ビームスプリッタ１１５、顕微鏡対物レンズ１０５、三角プリズム１３４、ズームレンズ１０６と進み、ＣＣＤカメラ１０７に輝点となって結像する。非球面１２０を回転させると、ＣＣＤカメラ１０７上の反射してきた光束の輝点は曲線を描き、ＣＣＤカメラ１０７上で回るが、この輝点の軌跡を解析することで被検非球面レンズ１２１の非球面１２０の偏心δｒと傾きεｒをその方位角εθ、δθと共に求めることができる。

【００４０】ところが、上述の２件の特許では、軌跡を解析するのに近軸計算及びローカル曲率に基づく近軸計算を用いていたため、必ずしも精度が良いとは言えなかった。

【００４１】そこで、本発明では、偏心測定機１４１の光学系の全ての面の光学設計データ、つまり、各面の

ｒ：曲率半径（非球面の場合は面の方程式）

ｄ：次の面までの距離

ｎ：媒質の屈折率

を計算機１５０に入力しておき、被検非球面のεｒ、δｒ並びにεｒ、δｒの方位角εθ、δθを変数としてＣＣＤカメラ１０７で観測した被検非球面レンズ１２１を回転させたときの軌跡にリアルレイトレースした輝点の軌跡が一致するようなεｒ、δｒ、εθ、δθの最適値を求める。

【００４２】このようにすれば、近軸光線での解析よりも精度良くεｒ、δｒ、εθ、δθを求めることかできる。

【００４３】なお、図中の符号１４９はＣＣＤカメラ１０７の出力を処理する信号処理回路であり、符号１５１はＴＶモニターである。

【００４４】$\varepsilon_x = \varepsilon r \cdot \cos \varepsilon\theta$

$\varepsilon_y = \varepsilon r \cdot \sin \varepsilon\theta$

$\delta_x = \delta r \cdot \cos \delta\theta$

$\delta_y = \delta r \cdot \sin \delta\theta$

であるから、εｒ、δｒ、εθ、δθの代わりに偏心量の成分ε_x、ε_y、δ_x、δ_yを求めてもよい。

【００４５】図１２に、上記εｒ、δｒ、εθ、δθの定義を示す。

【００４６】次に、図１３はリアルレイトレースを用いた心出顕微鏡１６０の例を示す図であり、この心出顕微鏡１６０は、１枚のレンズの偏心測定、レンズの１面の偏心測定、複数のレンズの接合のために、それぞれのレンズの偏心を調べつつ接合するときに用いられる。

【００４７】この心出顕微鏡１６０において、光源１６１から出た光は、ターゲットのピンホール１６２、採光レンズ１６３、ビームスプリッタ（ハーフプリズム）１１５を通り、非検面１６４に入射する。非検面１６４で反射した光束は、ビームスプリッタ（ハーフプリズム）１１５、変倍系１７１を有する光学系１０２、ハーフミラー１６７、結像レンズ１６６と進み、ＣＣＤカメラ１０７に輝点となって結像する。被検レンズ１６５を回転させたとき、ＣＣＤカメラ１０７上の輝点の位置又は軌跡から非検面１６４の偏心を求めることができる。ＣＣＤカメラ１０７の代わりに、焦点板１６８上の輝点の位置又は軌跡から、接眼レンズ１６９を介して眼１７０で観察して非検面１６４の偏心を求めてもよい。

【００４８】ここで、ピンホール１６２の採光レンズ１６３による像は、非検面１６４の球心にできるのではなく、その球心から外れた位置にできるものでもよく、図１３はそのような場合を図示している。それを不等倍結像の状態という。同様にして、非検面１６４の下方の面１７２、１７３、１７４の偏心を求めることができる。

【００４９】輝点の位置又は軌跡から被検面び偏心を求めるには、従来、近軸理論で解析していた。しかし、心出顕微鏡１６０の光学系の収差（特に歪曲収差）のため、精度がやや悪かった。そこで、本発明では、心出顕微鏡１６０の光学系の各面の

ｒ：曲率半径（非球面の場合は面の方程式）

ｄ：次の面までの距離

ｎ：媒質の屈折率

を計算機１５０に入力しておき、ＣＣＤカメラ１０７上の輝点の位置又は軌跡にリアルレイトレースした輝点の位置が略一致するような非検面１６４の偏心を求めるこ

とで、非検面１６４の偏心を知ることができる。

【００５０】次に、複数面を有するレンズ系に非球面で構成されたレンズ面が含まれている場合の偏心測定の実施例を示す。非球面は一義的に決まる非球面軸が存在するため、例えばレンズ面の傾き ε とズレ量 δ の偏心を表すパラメータが必要となる。偏心を表すパラメータは、光軸と直交し、かつ、それぞれが直交する２方向の成分（ε_x，ε_y）、（δ_x，δ_y）で表してもよい。また、図１２に非球面の偏心の定義を示すように、極座標（εr，$\varepsilon\theta$）、（δr，$\delta\theta$）等でもよい。これらの偏心を表わすパラメータを求めるには以下のようにすればよい。

【００５１】一般的に、測定しようとするレンズ面が非球面であるとき、この面に傾き ε がある場合の指標の反射像の光強度分布と、この面にズレ量 δ がある場合の指標の反射像の光強度分布は異なるため、測定された指標の反射像の光強度分布を目標値として、例えば被測定面の傾き ε とズレ量 δ を変数にして、リアルレイトレース又は近軸光線追跡を行い、傾き ε とズレ量 δ を最適化することで、偏心を表すパラメータを求めることができる。

【００５２】上記の光強度分布は、検出器で検出された光の強度分布の形状、及び、幾何光学的あるいは波動光学的に計算された光の強度分布を意味する。

【００５３】また、被検光学系の評価を行うためには、偏心を表すパラメータの中、必要とされる少なくとも一つのパラメータを求めればよい。

【００５４】また、図７において、光源５２から射出する光束の中一部の光線だけを被検光学系に入射させ、この光線と光軸とのなす角度をさまざまに変化させ、それぞれの角度に対して被検面から反射する光線の位置を検出し、それぞれの状態に対してリアルレイトレース又は近軸光線追跡を行い、全ての状態において測定された光線の位置と光線追跡で求めた光線位置との差が小さくなるよう、傾き ε とズレ量 δ を最適化することでも、偏心を表すパラメータを求めることができる。

【００５５】また、図１４に示すように、マイクロレンズアレイ６２で点光源像群を作り、それを投影レンズ６３で被検面６１に投影し、被検面６１で反射若しくは屈折した光をハーフミラー６４を介して（被検面６１で反射させる場合）撮像素子６５で検出し、図１５に例示するような各点光源の像を得て、各点光源像の位置を目標としてリアルレイトレース又は近軸光線追跡を行い、全ての状態において測定された点光源像の位置と光線追跡で求めた点光源像の位置との差が小さくなるよう、傾き ε とズレ量 δ を最適化することでも、偏心を表すパラメータを求めることができる。

【００５６】また、図１６に示すように、シャックハルトマン法の応用例として、被検光学素子又は光学系７１を透過した光をコリメートレンズ７２を介してマイクロレンズアレイ７３に導いて点像群を作り、リレーレンズ７４を経てその点像群を撮像素子７５で検出し、各点像の位置を目標としてリアルレイトレース又は近軸光線追跡を行い、全ての状態において測定された点光源像の位置と光線追跡で求めた点光源像の位置との差が小さくなるよう、各面の傾き ε とズレ量 δ を最適化することでも、偏心を表すパラメータを求めることができる。

【００５７】また、測定しようとする非球面を含むレンズ単体において、レンズの前面と後面との間の面間偏心 ε_L が、面間偏心測定機等で得られている場合には、前面及び後面単体での軸の光軸に対する傾き ε（それぞれ ε_1、ε_2）とズレ量 δ（それぞれ δ_1、δ_2）と、指標の反射像の測定から得られた前面の傾き量 ε_1'、後面の傾き量 ε_2'、及び、ε_L、及び、前面の近軸曲率半径 R_1、後面の近軸曲率半径 R_2、レンズ厚Ｔから、前面と後面の傾き ε とズレ量 δ を、以下のように計算することができる。なお、偏心を表するパラメータ ε_1、ε_2、ε_1'、ε_2'、ε_L、δ_1、δ_2 は、ｘ、ｙそれぞれの成分を表している。

【００５８】

$$\varepsilon_1' = \varepsilon_1 + \delta_1 / R_1 \quad \cdots (3)$$

$$\varepsilon_2' = \varepsilon_2 + \delta_2 / R_2 \quad \cdots (4)$$

$$\varepsilon_2 = \varepsilon_1 + \varepsilon_L \quad \cdots (5)$$

$$\delta_2 = \delta_1 + T\varepsilon_1 \quad \cdots (6)$$

式（３）～（６）から、

$$\delta_1 = (R_1 R_2 + R_1 T)\,\varepsilon_1' / (R_2 - R_1 + T) - R_1 R_2\,(\varepsilon_2' - \varepsilon_L) / (R_2 - R_1 + T) \quad \cdots (7)$$

$$\delta_2 = R_1 R_2\,\varepsilon_1' / (R_2 - R_1 + T) - (R_1 R_2 - R_2 T)\,(\varepsilon_2' - \varepsilon_L) / (R_2 - R_1 + T) \quad \cdots (8)$$

$$\varepsilon_1 = -R_1\,\varepsilon_1' / (R_2 - R_1 + T) + R_2\,(\varepsilon_2' - \varepsilon_L) / (R_2 - R_1 + T) \quad \cdots (9)$$

$$\varepsilon_2 = \varepsilon_1' + \varepsilon_L \quad \cdots (10)$$

以上の計算は、光学系の近軸的な性質を基にした計算であり、式（７）～（１０）の方程式で偏心量を求めることができるし、リアルレイトレースで被検光学系の各面の偏心を計算する場合に、非球面を含むレンズの両面の

面間偏心を束縛条件として計算することもできる。

【００５９】なお、言うまでもなく、式（７）～（１０）と数学的に同値な方程式（例えば、極座標に変換したもの）を用いてももちろんよい。

【００６０】ところで、複数面を有するレンズ系の各面の測定をオートコリメーション法（図７）を用いて行う場合、測定しようとする面５１の見かけ上の曲率中心、すなわち、被測定面５１と観察系との間に存在する別の面によって結像される被測定面５１の曲率中心の像の位置に、指標若しくは光源像を投影し、被検面５１による等倍の反射像を、その指標若しくは光源像の投影位置と同じ位置に生じさせたときに、測定しようとするレンズ面以外から反射された指標像若しくは光源像が、測定しようとするレンズ面５１による指標若しくは光源像の近傍に生じることが有り得る。この場合には、どちらが測定しようとするレンズ面による指標像若しくは光源像かの区別が困難である。

【００６１】そこで、このような場合には、測定しようとする面の見かけ上の曲率中心、すなわち、被測定面５１と観察系との間に存在する別の面によって結像される被測定面５１の曲率中心の像の位置から光軸に沿った方向にずらした位置に指標若しくは光源像を投影する。その様子を図１７に示す。図７の光源５２若しくはコリメータレンズ５３の位置を光軸に沿ってずらせた場合に相当する。このとき、指標若しくは光源像を投影した位置とのその反射像の位置は異なり、倍率も等倍ではなくなる。

【００６２】また、上記した測定しようとするレンズ面５１以外から反射される指標の像若しくは光源像の位置もずれ、一般に測定しようとするレンズ面５１による反射像の位置のずれ量と測定しようとするレンズ面以外からの反射像の位置ずれ量は異なるため、測定しようとするレンズ面５１から反射される指標の像若しくは光源像のずれ量を計算で求めておき、この位置に結像される指標の像若しくは光源像の反射像を検出するようにすることで、測定しようとするレンズ面５１による指標像若しくは光源像を区別することができる。また、投影する指標若しくは光源像に対する指標若しくは光源像の反射像の倍率の絶対値を１より大きくすることにより、等倍で結像する場合よりも偏心測定精度を向上させることができる。また、被検面で反射した光線の代わりに被検面で屈折した光線を検出する方法でもよい。

【００６３】次に、リアルレイトレースを用いて光学素子の屈折率分布測定・評価・解析を行う実施例を、図１８を用いて説明する。

【００６４】Ｈｅ－Ｎｅレーザー８１からのレーザー光をビームスプリッタ８２で２つの光路に分割し、一方を被検光学素子８３に入射させ、残る一方をその被検光学素子８３の設計値通りの光学性能を持つ基準光学系８４に入射させ、双方の光学系を透過した光束をビームスプリッタ８５で合成し、スクリーン８６上に干渉縞が発生するように投影する。干渉縞の像はテレビカメラで取り込み、計算機に入力して縞の解析を行い、スクリーン８６上の光束内における位相差分布を求める。

【００６５】このような装置により測定される位相差分布は、被検光学素子８３に平行光束を入射させた場合の、射出瞳面における波面収差に該当する。

【００６６】一般に、屈折率分布は、

$$n(r)=n_0+n_2r^2+n_4r^4+n_6r^6+\cdots\quad\cdots(11)$$

の形で表せられる。

【００６７】被検光学素子８３の光軸方向の厚さが十分に小さくなく、被検光学素子８３内での光線の屈曲が無視できない場合には、リアルレイトレースによって計算した波面収差が、測定した波面収差に等しくなるように、式（１１）の係数n_2、n_4、n_6を変数として屈折率分布の最適化を行う。

【００６８】この場合、被検光学素子８３に平行光を入射させた場合の射出波面の、基準光学系８４に平行光を入射させた場合の射出波面からのズレを測定していると考えられ、基準光学系８４の収差が無視できる程小さければ、射出波面は球面となるため、被検光学素子８３に平行光を入射させた場合の射出波面の、基準光学系８４に平行光を入射させた場合の射出波面からのズレは、被検光学素子８３に平行光を入射させた場合の波面収差と一致する。

【００６９】そのため、屈折率分布形状を式（１１）で定義した媒質の各屈折率分布係数を、初期状態を設計値とする変数として、リアルレイトレースを行い、その射出波面、すなわち波面収差を、測定値にフィッティングさせるように最適化を行えば、各係数が得られる。

【００７０】以上の本発明の光学素子又は光学系の偏心測定方法等は、次のように構成することができる。

【００７１】〔１〕　被測定光学素子又は光学系に光を入射し、その光学素子又は光学系から射出される光の状態を測定し、その測定値よりリアルレイトレースを用いることにより前記光学素子又は光学系の偏心量を求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００７２】〔２〕　被測定光学素子又は光学系に光線を入射し、その光学素子又は光学系から射出される光線の状態を測定し、その測定値よりリアルレイトレースを用いることにより前記光学素子又は光学系の偏心量を求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００７３】〔３〕　被測定光学素子又は光学系に光束を入射し、その光学素子又は光学系から射出される光束の状態を測定し、その測定値よりリアルレイトレースを用いることにより前記光学素子又は光学系の偏心量を求めることを特徴とする光学素子又は光学系の偏心測定方

法又は測定機又は測定されたもの。

【００７４】〔４〕　被検光学素子又は光学系中の被検面に光を入射させる手段と、その光が被検光学素子又は光学系中の被検面より反射又は屈折した光を検出する光検出手段と、前記被検面で反射又は屈折された光を前記光検出手段に導く光学素子又は光学系で構成される光学素子又は光学系の各面の偏心を測定する偏心測定機において、前記光学素子又は光学系中の被測定面より前記光検出手段までの光学素子又は光学系の全光学素子の設計値若しくは測定値を基に、光線追跡の計算を行い、前記光検出手段における光の状態が、測定された光の状態と等しくなるような被検面の偏心量を計算で求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００７５】〔５〕　被検光学素子又は光学系中の被検面に光線を入射させる手段と、その光線が被検光学素子又は光学系中の被検面より反射又は屈折した光線を検出する光線検出手段と、前記被検面で反射又は屈折された光線を前記光線検出手段に導く光学素子又は光学系で構成される光学素子又は光学系の各面の偏心を測定する偏心測定機において、前記光学素子又は光学系中の被測定面より前記光線検出手段までの光学素子又は光学系の全光学素子の設計値若しくは測定値を基に、光線追跡の計算を行い、前記光線検出手段における光線の状態が、測定された光線の状態と等しくなるような被検面の偏心量を計算で求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００７６】〔６〕　被検光学素子又は光学系中の被検面に光束を入射させる手段と、その光束が被検光学素子又は光学系中の被検面より反射又は屈折した光束を検出する光束検出手段と、前記被検面で反射又は屈折された光束を前記光束検出手段に導く光学素子又は光学系で構成される光学素子又は光学系の各面の偏心を測定する偏心測定機において、前記光学素子又は光学系中の被測定面より前記光束検出手段までの光学素子又は光学系の全光学素子の設計値若しくは測定値を基に、光線追跡の計算を行い、前記光束検出手段における光束の状態が、測定された光束の状態と等しくなるような被検面の偏心量を計算で求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００７７】〔７〕　被測定光学素子又は光学系あるいは測定機の光学素子又は光学系の製造誤差を含んだ光学素子又は光学系でリアルレイトレースを行うことを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００７８】〔８〕　測定機の光学素子又は光学系内部の変動量を測定し、変動量を考慮した光学素子又は光学系でリアルレイトレースを行うことを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００７９】〔９〕　光学素子又は光学系の前面から１面ずつ測定して偏心量を求め、次の面では前に求めた偏心量を含んだ光学素子又は光学系でリアルレイトレースを行い、その面の偏心量を求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００８０】〔１０〕　前記測定値を目標値、求める面の偏心量を未知数とした方程式の解法処理をリアルレイトレースを用いて行うことを特徴とする上記１から３の何れか１項記載の光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００８１】〔１１〕　前記測定値を目標値、任意の位置又は任意の軸を基準とした複数の面あるいはレンズ群の偏心量を未知数とした方程式の解法処理をリアルレイトレースを用いて行うことを特徴とする上記１から３の何れか１項記載の光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００８２】〔１２〕　前記未知数の算出に、最適化処理を用いることを特徴とする上記１０又は１１記載の光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００８３】〔１３〕　波動光学的点像強度分布を評価関数とすることを特徴とする上記１２記載の光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００８４】〔１４〕　光束の像を測定する場合の結像関係が等倍結像あるいは不等倍結像の何れかを用いることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００８５】〔１５〕　ローカル近軸量を用いたオートコリメーション法又は不等倍像法により偏心量を求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００８６】〔１６〕　測定された指標の反射像の光強度分布又は位置を目標値として、非球面である被測定面の偏心量を変数にして光線追跡を行い、偏心量を最適化することで少なくとも一つの偏心量を求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００８７】〔１７〕　測定された指標の反対像の光強度分布又は位置を目標値として、非球面である被測定面の傾きと偏り量を変数にして光線追跡を行い、傾きと偏り量を最適化することで、傾きと偏り量のそれぞれの要素の中少なくとも一つの偏心を表すパラメータを求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００８８】〔１８〕　測定された指標の反射像の光強度分布又は位置を目標値として、非球面である被測定面の光軸と直交しかつそれぞれが直交する２方向の傾きと偏り量を変数にして光線追跡を行い、光軸と直交しかつ

それぞれが直交する２方向の傾きと偏り量を最適化することで、光軸と直交しかつそれぞれが直交する２方向の傾きと偏り量の少なくとも一つの偏心を表すパラメータを求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００８９】〔１９〕　被測定光学素子又は光学系に光線を入射させ、この光線と光軸とのなす角度をさまざまに変化させ、それぞれの角度に対して被検面からの反射又は屈折する光線の位置を検出し、全ての状態において測定された光線の位置と光線追跡で求めた光線位置との差が小さくなるように偏心量を最適化することで、少なくとも一つの偏心量を求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００９０】〔２０〕　被測定光学素子又は光学系に光線を入射させ、この光線と光軸とのなす角度をさまざまに変化させ、それぞれの角度に対して被検面からの反射又は屈折する光線の位置を検出し、全ての状態において測定された光線の位置と光線追跡で求めた光線位置との差が小さくなるように傾きと偏り量を最適化することで、傾きと偏り量の少なくとも一つの偏心を表すパラメータを求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００９１】〔２１〕　被測定光学素子又は光学系に光線を入射させ、この光線と光軸とのなす角度をさまざまに変化させ、それぞれの角度に対して被検面からの反射又は屈折する光線の位置を検出し、全ての状態において測定された光線の位置と光線追跡で求めた光線位置との差が小さくなるように、光軸と直交しかつそれぞれが直交する２方向の傾きと偏り量を最適化することで、光軸と直交しかつそれぞれが直交する２方向の傾きと偏り量の少なくとも一つの偏心を表すパラメータを求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００９２】〔２２〕　光学系中若しくは単体の非球面レンズにおいて、レンズの前面と後面との間の既知の面間偏心 ε_L を用い、指標の反射像の測定から得られた前面の傾き量 ε_1'、後面の傾き量 ε_2'、及び、ε_L、及び、前面の近軸曲率半径 R_1、後面の近軸曲率半径 R_2、レンズ厚Ｔから、以下の式若しくは数学的に同値の式により前面と後面の傾き ε_1 と ε_2、偏り量 δ_1 と δ_2 を計算することを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００９３】

$$\delta_1 = (R_1 R_2 + R_1 T)\,\varepsilon_1' / (R_2 - R_1 + T) - R_1 R_2 (\varepsilon_2' - \varepsilon_L) / (R_2 - R_1 + T) \quad \cdots (7)$$

$$\delta_2 = R_1 R_2\,\varepsilon_1' / (R_2 - R_1 + T) - (R_1 R_2 - R_2 T)(\varepsilon_2' - \varepsilon_L) / (R_2 - R_1 + T) \quad \cdots (8)$$

$$\varepsilon_1 = -R_1\,\varepsilon_1' / (R_2 - R_1 + T) + R_2 (\varepsilon_2' - \varepsilon_L) / (R_2 - R_1 + T) \quad \cdots (9)$$

$$\varepsilon_2 = \varepsilon_1' + \varepsilon_L \quad \cdots (10)$$

〔２３〕　光学系中若しくは単体の球面若しくは非球面レンズにおいて、レンズの前面と後面との間の既知の面間偏心を用いてその面間偏心を束縛条件とし、リアルレイトレースを用いて偏心を表すパラメータを求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００９４】〔２４〕　測定しようとする面のみかけ上の曲率中心、すなわち、被測定面と偏心測定機の観察系との間に存在する別の面によって結像される被測定面の曲率中心の像の位置から光軸に沿った方向にずらした位置に指標を投影し、測定しようとするレンズ面から反射される指標の像のずれ量を計算で求めておき、この位置に結像される指標の像の反射像を検出することを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００９５】〔２５〕　投影する指標に対する指標の反射像の倍率の絶対値が１より大きくすることを特徴とする上記２４記載の光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００９６】〔２６〕　リアルレイトレースを用いることを特徴とする上記２４又は２５記載の光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００９７】〔２７〕　光源と、光源からの光を複数の点光源群像に分割する手段と、前記点光源像群を被検面近傍に投影する手段と、前記被検面で反射ないし屈折した前記点光源像群を検出する検出手段と、前記被検面で反射ないし屈折した前記点光源像群を前記検出手段に導く手段とを備え、検出された点光源像群の位置を基に近軸光線追跡若しくはリアルレイトレースを行い、前記被検面の偏心を表すパラメータを求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００９８】〔２８〕　光学素子若しくは光学系を透過した光を複数の点光源像群に分割する手段と、前記点光源像群を検出する検出手段と、前記点光源像群を前記検出手段に導く手段とを備え、検出された点光源像群の位置を基に近軸光線追跡若しくはリアルレイトレースを行い、前記被検面の偏心を表すパラメータを求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【００９９】〔２９〕　光源と、光源からの光を複数の光束群に分割する手段と、前記光束群を被検面近傍に投影する手段と、前記被検面で反射ないし屈折した前記光束群を検出する検出手段と、前記被検面で反射ないし屈折した前記光束群を前記検出手段に導く手段とを備え、検出された光束群の位置を基に近軸光線追跡若しくはリアルレイトレースを行い、前記被検面の偏心を表すパラメータを求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【０１００】〔３０〕　光学素子若しくは光学系を透過した光を複数の光束群に分割する手段と、前記光束群を検出する検出手段と、前記光束群を前記検出手段に導く手段とを備え、検出された光束群の位置を基に近軸光線追跡若しくはリアルレイトレースを行い、前記被検面の偏心を表すパラメータを求めることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【０１０１】〔３１〕　カメラ、内視鏡、顕微鏡等のズームレンズの光学系を対象にしていることを特徴とする上記１から３０の何れか１項記載の光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【０１０２】〔３２〕　上記１から３０の何れか１項記載の処理方法を機械可読な形で記録したことを特徴とする記憶媒体。

【０１０３】〔３３〕　上記１から３０の何れか１項記載の処理方法を用いていることを特徴とする偏心測定処理装置。

【０１０４】〔３４〕　測定機を制御するコンピュータとリアルレイトレースを行うコンピュータとが同一であることを特徴とする光学素子又は光学系の偏心測定方法又は測定機又は測定されたもの。

【０１０５】〔３５〕　被測定光学素子又は光学系に光を入射し、その光学素子又は光学系から射出される光の状態を測定し、その測定値よりリアルレイトレースを用いることにより前記光学素子又は光学系の物理量を求めることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１０６】〔３６〕　被測定光学素子又は光学系に光線を入射し、その光学素子又は光学系から射出される光線の状態を測定し、その測定値よりリアルレイトレースを用いることにより前記光学素子又は光学系の物理量を求めることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１０７】〔３７〕　被測定光学素子又は光学系に光束を入射し、その光学素子又は光学系から射出される光束の状態を測定し、その測定値よりリアルレイトレースを用いることにより前記光学素子又は光学系の物理量を求めることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１０８】〔３８〕　被検光学素子又は光学系中の被検面に光を入射させる手段と、その光が被検光学素子又は光学系中の被検面より反射又は屈折した光を検出する光検出手段と、前記被検面で反射又は屈折された光を前記光検出手段に導く光学素子又は光学系で構成される光学素子又は光学系の各面の物理量を測定する物理量測定機において、前記光学素子又は光学系中の被測定面より前記光検出手段までの光学素子又は光学系の全光学素子の設計値若しくは測定値を基に、光線追跡の計算を行い、前記光検出手段における光の状態が、測定された光の状態と等しくなるような被検面の物理量を計算で求めることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１０９】〔３９〕　被検光学素子又は光学系中の被検面に光線を入射させる手段と、その光線が被検光学素子又は光学系中の被検面より反射又は屈折した光線を検出する光線検出手段と、前記被検面で反射又は屈折された光線を前記光線検出手段に導く光学素子又は光学系で構成される光学素子又は光学系の各面の物理量を測定する物理量測定機において、前記光学素子又は光学系中の被測定面より前記光線検出手段までの光学素子又は光学系の全光学素子の設計値若しくは測定値を基に、光線追跡の計算を行い、前記光線検出手段における光線の状態が、測定された光線の状態と等しくなるような被検面の物理量を計算で求めることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１１０】〔４０〕　被検光学素子又は光学系中の被検面に光束を入射させる手段と、その光束が被検光学素子又は光学系中の被検面より反射又は屈折した光束を検出する光束検出手段と、前記被検面で反射又は屈折された光束を前記光束検出手段に導く光学素子又は光学系で構成される光学素子又は光学系の各面の物理量を測定する物理量測定機において、前記光学素子又は光学系中の被測定面より前記光束検出手段までの光学素子又は光学系の全光学素子の設計値若しくは測定値を基に、光線追跡の計算を行い、前記光束検出手段における光束の状態が、測定された光束の状態と等しくなるような被検面の物理量を計算で求めることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１１１】〔４１〕　被測定光学素子又は光学系あるいは測定機の光学素子又は光学系の製造誤差を含んだ光学素子又は光学系でリアルレイトレースを行うことを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１１２】〔４２〕　測定機の光学素子又は光学系内部の変動量を測定し、変動量を考慮した光学素子又は光学系でリアルレイトレースを行うことを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１１３】〔４３〕　光学素子又は光学系の前面から１面ずつ測定して物理量を求め、次の面では前に求めた

物理量を含んだ光学素子又は光学系でリアルレイトレースを行い、その面の物理量を求めることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１１４】〔４４〕　前記測定値を目標値、求める面の物理量を未知数とした方程式の解法処理をリアルレイトレースを用いて行うことを特徴とする上記３５から３７の何れか１項記載の光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１１５】〔４５〕　前記測定値を目標値、任意の位置又は任意の軸を基準とした複数の面あるいはレンズ群の物理量を未知数とした方程式の解法処理をリアルレイトレースを用いて行うことを特徴とする上記３５から３７の何れか１項記載の光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１１６】〔４６〕　前記未知数の算出に、最適化処理を用いることを特徴とする上記４４又は４５記載の光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１１７】〔４７〕　波動光学的点像強度分布を評価関数とすることを特徴とする上記４６記載の光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１１８】〔４８〕　光束の像を測定する場合の結像関係が等倍結像あるいは不等倍結像の何れかを用いることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１１９】〔４９〕　被測定光学素子又は光学系に光線を入射させ、この光線と光軸とのなす角度をさまざまに変化させ、それぞれの角度に対して被検面からの反射又は屈折する光線の位置を検出し、全ての状態において測定された光線の位置と光線追跡で求めた光線位置との差が小さくなるように物理量を最適化することで、少なくとも一つの物理量を求めることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１２０】〔５０〕　被測定光学素子又は光学系に光線を入射させ、この光線と光軸とのなす角度をさまざまに変化させ、それぞれの角度に対して被検面からの反射又は屈折する光線の位置を検出し、全ての状態において測定された光線の位置と光線追跡で求めた光線位置との差が小さくなるように傾きと偏り量を最適化することで、傾きと偏り量の少なくとも一つの物理量を表すパラメータを求めることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１２１】〔５１〕　被測定光学素子又は光学系に光線を入射させ、この光線と光軸とのなす角度をさまざまに変化させ、それぞれの角度に対して被検面からの反射又は屈折する光線の位置を検出し、全ての状態において測定された光線の位置と光線追跡で求めた光線位置との差が小さくなるように、光軸と直交しかつそれぞれが直交する２方向の傾きと偏り量を最適化することで、光軸と直交しかつそれぞれが直交する２方向の傾きと偏り量の少なくとも一つの物理量を表すパラメータを求めることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１２２】〔５２〕　測定しようとする面のみかけ上の曲率中心、すなわち、被測定面と物理量測定機の観察系との間に存在する別の面によって結像される被測定面の曲率中心の像の位置から光軸に沿った方向にずらした位置に指標を投影し、測定しようとするレンズ面から反射される指標の像のずれ量を計算で求めておき、この位置に結像される指標の像の反射像を検出することを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１２３】〔５３〕　投影する指標に対する指標の反射像の倍率の絶対値が１より大きくすることを特徴とする上記５２記載の光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１２４】〔５４〕　リアルレイトレースを用いることを特徴とする上記５２又は５３記載の光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１２５】〔５５〕　光源と、光源からの光を複数の点光源群像に分割する手段と、前記点光源像群を被検面近傍に投影する手段と、前記被検面で反射ないし屈折した前記点光源像群を検出する検出手段と、前記被検面で反射ないし屈折した前記点光源像群を前記検出手段に導く手段とを備え、検出された点光源像群の位置を基に近軸光線追跡若しくはリアルレイトレースを行い、前記被検面の物理量を表すパラメータを求めることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１２６】〔５６〕　光学素子若しくは光学系を透過した光を複数の点光源像群に分割する手段と、前記点光源像群を検出する検出手段と、前記点光源像群を前記検出手段に導く手段とを備え、検出された点光源像群の位置を基に近軸光線追跡若しくはリアルレイトレースを行い、前記被検面の物理量を表すパラメータを求めることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１２７】〔５７〕　光源と、光源からの光を複数の光束群に分割する手段と、前記光束群を被検面近傍に投影する手段と、前記被検面で反射ないし屈折した前記光束群を検出する検出手段と、前記被検面で反射ないし屈折した前記光束群を前記検出手段に導く手段とを備え、検出された光束群の位置を基に近軸光線追跡若しくはリアルレイトレースを行い、前記被検面の物理量を表すパラメータを求めることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１２８】〔５８〕　光学素子若しくは光学系を透過

した光を複数の光束群に分割する手段と、前記光束群を検出する検出手段と、前記光束群を前記検出手段に導く手段とを備え、検出された光束群の位置を基に近軸光線追跡若しくはリアルレイトレースを行い、前記被検面の物理量を表すパラメータを求めることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１２９】〔５９〕　カメラ、内視鏡、顕微鏡等のズームレンズの光学系を対象にしていることを特徴とする上記３５から５８の何れか１項記載の光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１３０】〔６０〕　上記３５から５８の何れか１項記載の処理方法を用いていることを特徴とする物理量測定処理装置。

【０１３１】〔６１〕　測定機を制御するコンピュータとリアルレイトレースを行うコンピュータとが同一であることを特徴とする光学素子又は光学系の物理量測定方法又は測定機又は測定されたもの。

【０１３２】〔６２〕　被測定光学素子又は光学系に光を入射し、その光学素子又は光学系から射出される光の状態を測定し、その測定値よりリアルレイトレースを用いることにより前記光学素子又は光学系の屈折率分布型を求めることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１３３】〔６３〕　被測定光学素子又は光学系に光線を入射し、その光学素子又は光学系から射出される光線の状態を測定し、その測定値よりリアルレイトレースを用いることにより前記光学素子又は光学系の屈折率分布型を求めることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１３４】〔６４〕　被測定光学素子又は光学系に光束を入射し、その光学素子又は光学系から射出される光束の状態を測定し、その測定値よりリアルレイトレースを用いることにより前記光学素子又は光学系の屈折率分布型を求めることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１３５】〔６５〕　被検光学素子又は光学系中の被検面に光を入射させる手段と、その光が被検光学素子又は光学系中の被検面より反射又は屈折した光を検出する光検出手段と、前記被検面で反射又は屈折された光を前記光検出手段に導く光学素子又は光学系で構成される光学素子又は光学系の各面の屈折率分布型を測定する屈折率分布型測定機において、前記光学素子又は光学系中の被測定面より前記光検出手段までの光学素子又は光学系の全光学素子の設計値若しくは測定値を基に、光線追跡の計算を行い、前記光検出手段における光の状態が、測定された光の状態と等しくなるような被検面の屈折率分布型を計算で求めることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１３６】〔６６〕　被検光学素子又は光学系中の被検面に光線を入射させる手段と、その光線が被検光学素子又は光学系中の被検面より反射又は屈折した光線を検出する光線検出手段と、前記被検面で反射又は屈折された光線を前記光線検出手段に導く光学素子又は光学系で構成される光学素子又は光学系の各面の屈折率分布型を測定する屈折率分布型測定機において、前記光学素子又は光学系中の被測定面より前記光線検出手段までの光学素子又は光学系の全光学素子の設計値若しくは測定値を基に、光線追跡の計算を行い、前記光線検出手段における光線の状態が、測定された光線の状態と等しくなるような被検面の屈折率分布型を計算で求めることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１３７】〔６７〕　被検光学素子又は光学系中の被検面に光束を入射させる手段と、その光束が被検光学素子又は光学系中の被検面より反射又は屈折した光束を検出する光束検出手段と、前記被検面で反射又は屈折された光束を前記光束検出手段に導く光学素子又は光学系で構成される光学素子又は光学系の各面の屈折率分布型を測定する屈折率分布型測定機において、前記光学素子又は光学系中の被測定面より前記光束検出手段までの光学素子又は光学系の全光学素子の設計値若しくは測定値を基に、光線追跡の計算を行い、前記光束検出手段における光束の状態が、測定された光束の状態と等しくなるような被検面の屈折率分布型を計算で求めることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１３８】〔６８〕　被測定光学素子又は光学系あるいは測定機の光学素子又は光学系の製造誤差を含んだ光学素子又は光学系でリアルレイトレースを行うことを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１３９】〔６９〕　測定機の光学素子又は光学系内部の変動量を測定し、変動量を考慮した光学素子又は光学系でリアルレイトレースを行うことを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１４０】〔７０〕　光学素子又は光学系の前面から１面ずつ測定して屈折率分布型を求め、次の面では前に求めた屈折率分布型を含んだ光学素子又は光学系でリアルレイトレースを行い、その面の屈折率分布型を求めることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１４１】〔７１〕　前記測定値を目標値、求める面の屈折率分布型を未知数とした方程式の解法処理をリアルレイトレースを用いて行うことを特徴とする上記６２から６４の何れか１項記載の光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１４２】〔７２〕　前記測定値を目標値、任意の位

置又は任意の軸を基準とした複数の面あるいはレンズ群の屈折率分布型を未知数とした方程式の解法処理をリアルレイトレースを用いて行うことを特徴とする上記６２から６４の何れか１項記載の光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１４３】〔７３〕　前記未知数の算出に、最適化処理を用いることを特徴とする上記７１又は７２記載の光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１４４】〔７４〕　波動光学的点像強度分布を評価関数とすることを特徴とする上記７３記載の光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１４５】〔７５〕　光束の像を測定する場合の結像関係が等倍結像あるいは不等倍結像の何れかを用いることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１４６】〔７６〕　被測定光学素子又は光学系に光線を入射させ、この光線と光軸とのなす角度をさまざまに変化させ、それぞれの角度に対して被検面からの反射又は屈折する光線の位置を検出し、全ての状態において測定された光線の位置と光線追跡で求めた光線位置との差が小さくなるように屈折率分布型を最適化することで、少なくとも一つの屈折率分布型を求めることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１４７】〔７７〕　被測定光学素子又は光学系に光線を入射させ、この光線と光軸とのなす角度をさまざまに変化させ、それぞれの角度に対して被検面からの反射又は屈折する光線の位置を検出し、全ての状態において測定された光線の位置と光線追跡で求めた光線位置との差が小さくなるように傾きと偏り量を最適化することで、傾きと偏り量の少なくとも一つの屈折率分布型を表すパラメータを求めることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１４８】〔７８〕　被測定光学素子又は光学系に光線を入射させ、この光線と光軸とのなす角度をさまざまに変化させ、それぞれの角度に対して被検面からの反射又は屈折する光線の位置を検出し、全ての状態において測定された光線の位置と光線追跡で求めた光線位置との差が小さくなるように、光軸と直交しかつそれぞれが直交する２方向の傾きと偏り量を最適化することで、光軸と直交しかつそれぞれが直交する２方向の傾きと偏り量の少なくとも一つの屈折率分布型を表すパラメータを求めることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１４９】〔７９〕　測定しようとする面のみかけ上の曲率中心、すなわち、被測定面と屈折率分布型測定機の観察系との間に存在する別の面によって結像される被測定面の曲率中心の像の位置から光軸に沿った方向にずらした位置に指標を投影し、測定しようとするレンズ面から反射される指標の像のずれ量を計算で求めておき、この位置に結像される指標の像の反射像を検出することを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１５０】〔８０〕　投影する指標に対する指標の反射像の倍率の絶対値が１より大きくすることを特徴とする上記７９記載の光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１５１】〔８１〕　リアルレイトレースを用いることを特徴とする上記７９又は８０記載の光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１５２】〔８２〕　光源と、光源からの光を複数の点光源群像に分割する手段と、前記点光源像群を被検面近傍に投影する手段と、前記被検面で反射ないし屈折した前記点光源像群を検出する検出手段と、前記被検面で反射ないし屈折した前記点光源像群を前記検出手段に導く手段とを備え、検出された点光源像群の位置を基に近軸光線追跡若しくはリアルレイトレースを行い、前記被検面の屈折率分布型を表すパラメータを求めることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１５３】〔８３〕　光学素子若しくは光学系を透過した光を複数の点光源像群に分割する手段と、前記点光源像群を検出する検出手段と、前記点光源像群を前記検出手段に導く手段とを備え、検出された点光源像群の位置を基に近軸光線追跡若しくはリアルレイトレースを行い、前記被検面の屈折率分布型を表すパラメータを求めることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１５４】〔８４〕　光源と、光源からの光を複数の光束群に分割する手段と、前記光束群を被検面近傍に投影する手段と、前記被検面で反射ないし屈折した前記光束群を検出する検出手段と、前記被検面で反射ないし屈折した前記光束群を前記検出手段に導く手段とを備え、検出された光束群の位置を基に近軸光線追跡若しくはリアルレイトレースを行い、前記被検面の屈折率分布型を表すパラメータを求めることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１５５】〔８５〕　光学素子若しくは光学系を透過した光を複数の光束群に分割する手段と、前記光束群を検出する検出手段と、前記光束群を前記検出手段に導く手段とを備え、検出された光束群の位置を基に近軸光線追跡若しくはリアルレイトレースを行い、前記被検面の屈折率分布型を表すパラメータを求めることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１５６】〔８６〕　カメラ、内視鏡、顕微鏡等のズームレンズの光学系を対象にしていることを特徴とする上記６２から８５の何れか１項記載の光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１５７】〔８７〕　上記６２から８５の何れか１項記載の処理方法を用いていることを特徴とする屈折率分布型測定処理装置。

【０１５８】〔８８〕　測定機を制御するコンピュータとリアルレイトレースを行うコンピュータとが同一であることを特徴とする光学素子又は光学系の屈折率分布型測定方法又は測定機又は測定されたもの。

【０１５９】

【発明の効果】以上の説明から明らかなように、本発明の光学素子又は光学系の物理量測定方法においては、被測定光学素子又は光学系から射出される光の状態を測定し、その測定値よりリアルレイトレースを用いることにより物理量を求めるので、高い精度で光学素子の単体又は組み合わせからなる光学系の物理量を表すパラメータを求めることができる。

【図面の簡単な説明】

【図１】本発明の偏心測定方法で用いるリアルレイトレースを説明するための図である。

【図２】本発明の１実施例の光学素子又は光学系の偏心測定方法を実施する処理装置のブロック図である。

【図３】図２の装置で行う処理のフローチャートである。

【図４】図３の偏心量算出処理の詳細を示すフローチャートである。

【図５】図４の偏心量算出処理を前面から後面に１面ずつ順に行う処理のフローチャートである。

【図６】反射像の基準軸からの振れ量を測定するための測定機の一例を示す図である。

【図７】オートコリメータで反射像の基準軸からの振れ量を測定する様子を説明するための図である。

【図８】像点位置算出のためのリアルレイトレースの一例を説明するための図である。

【図９】光束の重心位置、光束の広がり算出のためのリアルレイトレースの一例を説明するための図である。

【図１０】レンズ面、単レンズ、レンズ群の偏心量の定義の例を示す図である。

【図１１】斜入射法を用いた非球面偏心測定機に本発明のリアルレイトレース法を適用した実施例を示す図である。

【図１２】偏心量εｒ、δｒ、εθ、δθの定義を示す図である。

【図１３】本発明のリアルレイトレース法を用いた心出顕微鏡の例を示す図である。

【図１４】本発明によりマイクロレンズアレイで点光源像群を作って偏心量を求める配置を示す図である。

【図１５】図１４における各点光源の像の例を示す図である。

【図１６】本発明によるシャックハルトマン法の応用例を示す図である。

【図１７】本発明によりオートコリメータで不等倍像を作って振れ量を測定する様子を説明するための図である。

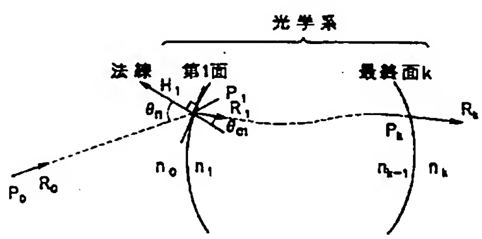
【図１８】本発明によりリアルレイトレースを用いて光学素子の屈折率分布測定・評価・解析を行う実施例を説明するための図である。

【符号の説明】

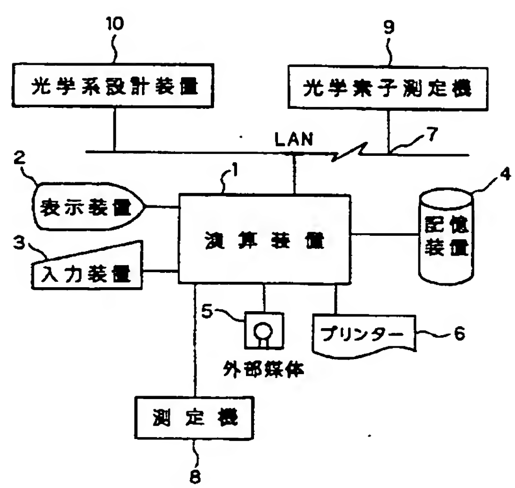
１…演算処理装置
２…表示装置
３…入力装置
４…記憶装置
５…外部媒体
６…プリンター
７…ＬＡＮ
８…測定機
９…光学素子測定機
１０…光学系設計装置
５１…被測定面
５２…光源（指標）
５３…コリメータレンズ
５４…像面
６１…被検面
６２…マイクロレンズアレイ
６３…投影レンズ
６４…ハーフミラー
６５…撮像素子
７１…被検光学素子又は光学系
７２…コリメートレンズ
７３…マイクロレンズアレイ
７４…リレーレンズ
７５…撮像素子
８１…Ｈｅ－Ｎｅレーザー
８２…ビームスプリッタ
８３…被検光学素子
８４…基準光学系
８５…ビームスプリッタ
８６…スクリーン
１０２…光学系
１０３…投影レンズ
１０５…顕微鏡対物レンズ
１０６…ズームレンズ
１０７…ＣＣＤカメラ
１１１…ミラー
１１５…ビームスプリッタ
１２０…非球面
１２１…被検非球面レンズ

１３４…三角プリズム
１４１…偏心測定機
１４９…信号処理回路
１５０…計算機
１５１…ＴＶモニター
１６０…心出顕微鏡
１６１…光源
１６２…ピンホール
１６３…採光レンズ
１６４…非検面
１６５…被検レンズ
１６６…結像レンズ
１６７…ハーフミラー
１６８…焦点板
１６９…接眼レンズ
１７０…眼
１７１…変倍系
１７２、１７３、１７４…光学面
２０１…半導体レーザー
２０２…測定用光学系
２０３…被測定レンズ
２０４…ビームスプリッタ
２０５…イメージローテータ
２０６…基準軸設定用光学系
２０７…ＣＣＤカメラ
２０８…モニタテレビ
２０９…ＣＲＴ
２１０…演算処理部

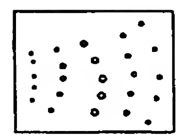
【図１】



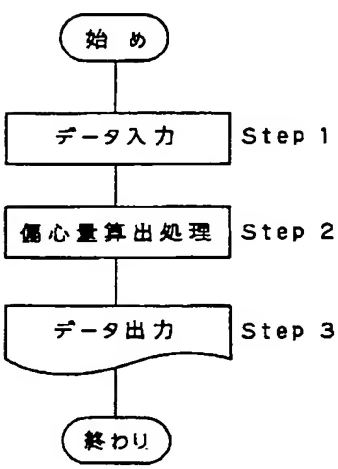
【図２】



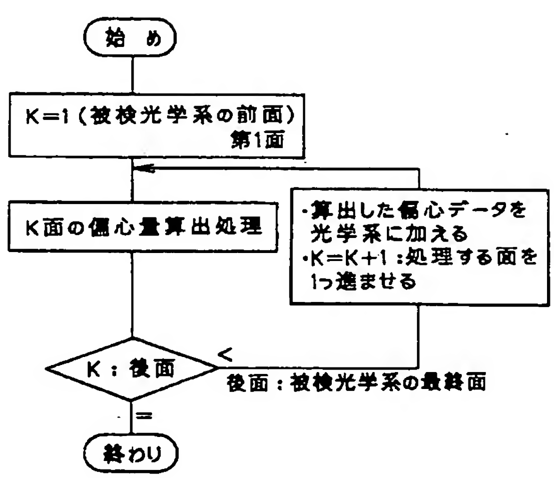
【図１５】



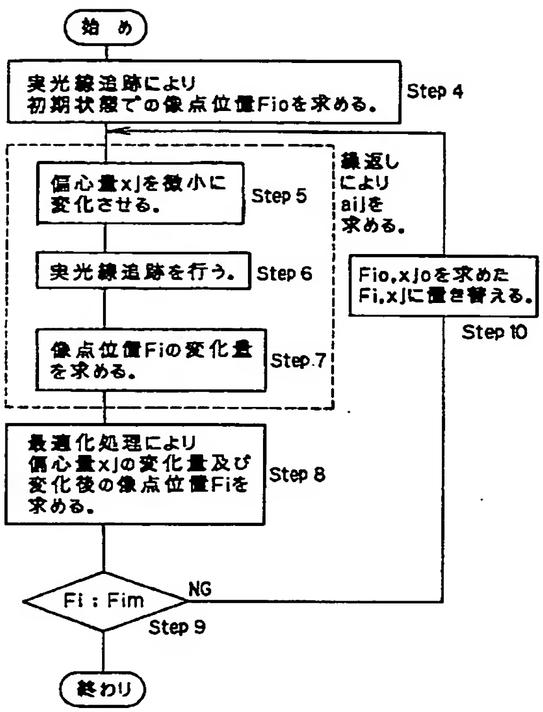
【図３】



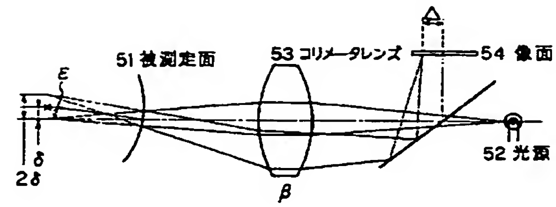
【図５】



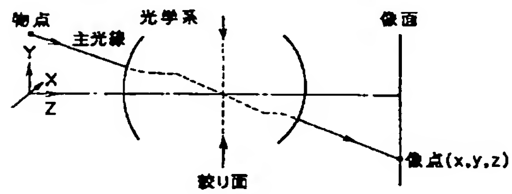
【図４】


始め
実光線追跡により
初期状態での像点位置Fioを求める。
Step 4
偏心量xjを微小に
変化させる。
Step 5
実光線追跡を行う。
Step 6
像点位置Fiの変化量
を求める。
Step 7
繰返し
により
aijを
求める。
Fio,xjoを求めた
Fi,xjに置き替える。
Step 10
最適化処理により
偏心量xjの変化量及び
変化後の像点位置Fiを
求める。
Step 8
Fi : Fim
NG
Step 9
終わり

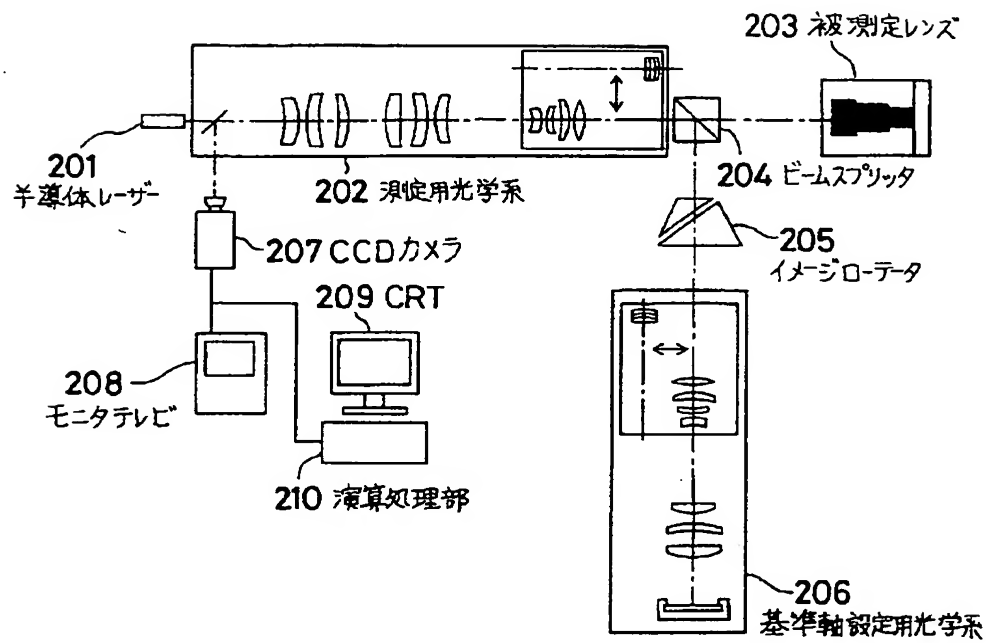
【図７】


51 被測定面
53 コリメータレンズ
54 像面
52 光源
ε
δ
2δ
β

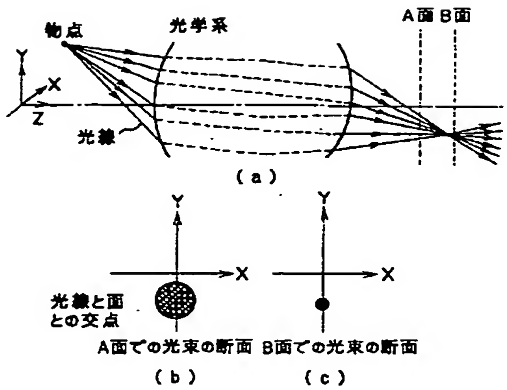
【図８】


物点
光学系
像面
主光線
Y
X
Z
絞り面
像点(x,y,z)

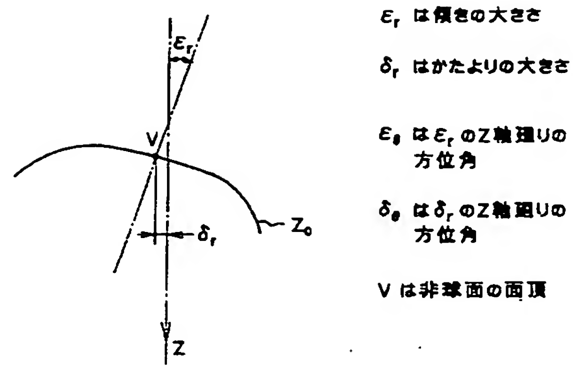
【図６】


203 被測定レンズ
201
半導体レーザー
202 測定用光学系
204 ビームスプリッタ
205
イメージローテータ
207 CCDカメラ
209 CRT
208
モニタテレビ
210 演算処理部
206
基準軸設定用光学系

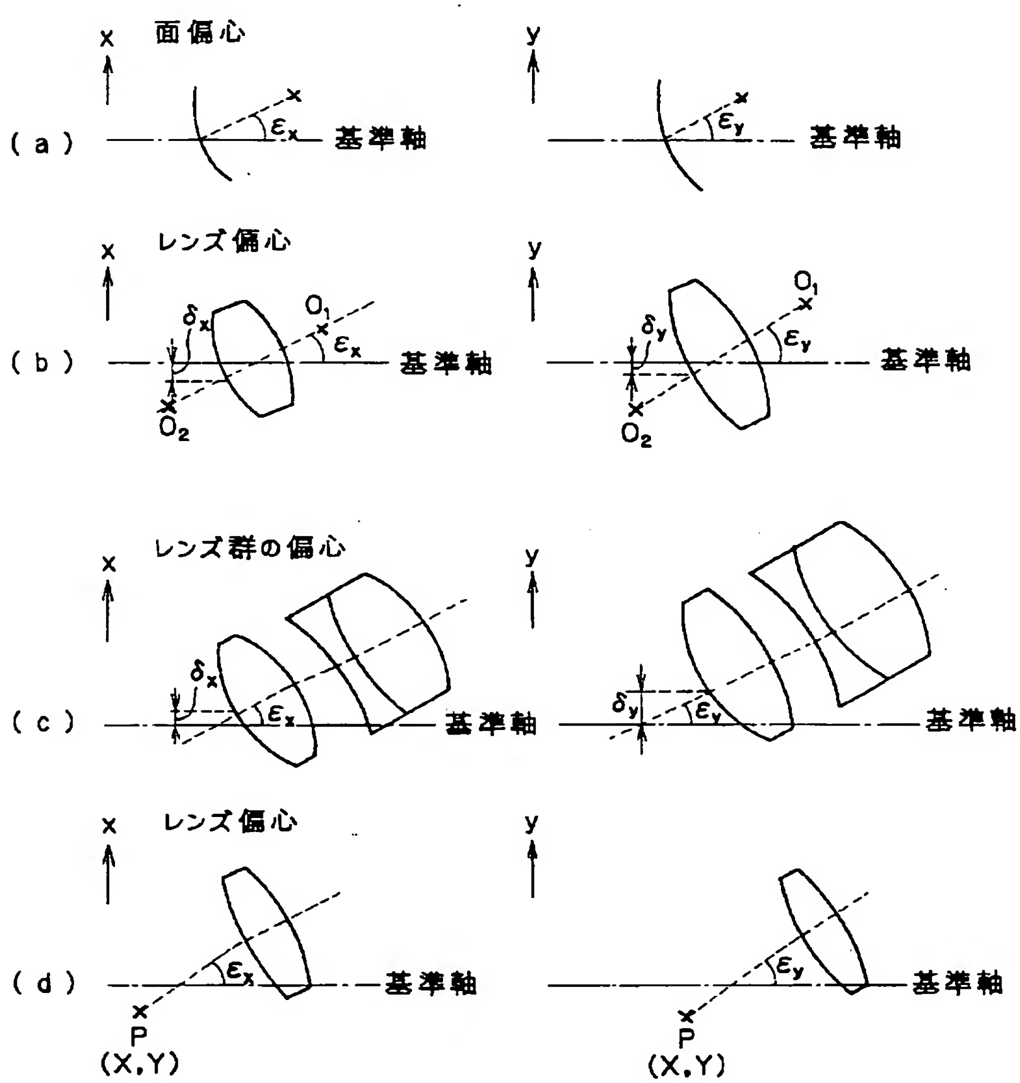
【図９】


物点
光学系
A面 B面
Y
X
Z
光線
(a)
Y
X
Y
X
光線と面
との交点
A面での光束の断面 B面での光束の断面
(b)
(c)

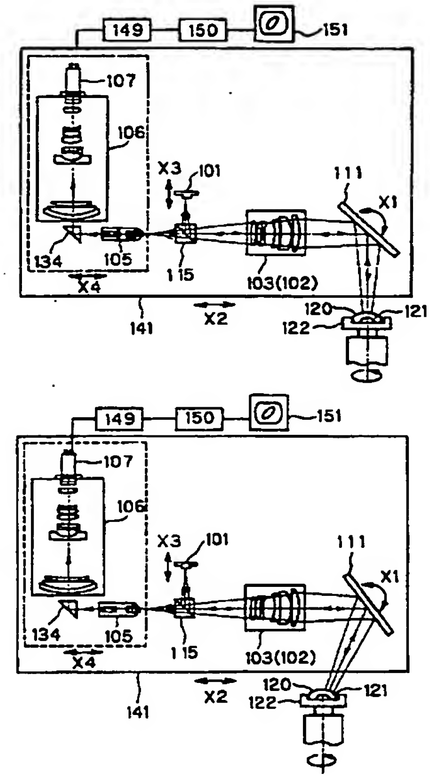
【図１２】


ε_r
V
δ_r
Z_0
Z
ε_r は傾きの大きさ
δ_r はかたよりの大きさ
ε_θ は ε_r のZ軸廻りの方位角
δ_θ は δ_r のZ軸廻りの方位角
V は非球面の面頂

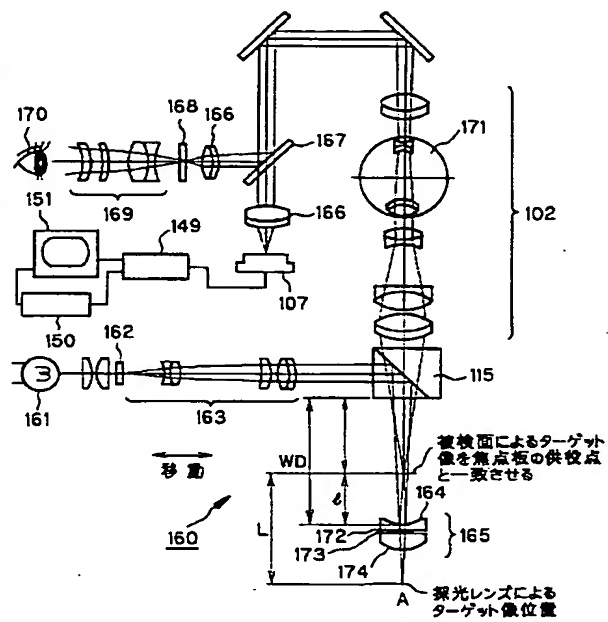
【図１０】


面偏心
(a)
x
ε_x
基準軸
y
ε_y
基準軸
レンズ偏心
(b)
x
δ_x
O_1
ε_x
基準軸
O_2
y
δ_y
O_1
ε_y
基準軸
O_2
レンズ群の偏心
(c)
x
δ_x
ε_x
基準軸
y
δ_y
ε_y
基準軸
レンズ偏心
(d)
x
ε_x
基準軸
P
(X,Y)
y
ε_y
基準軸
P
(X,Y)

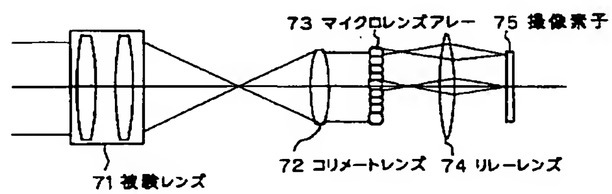
【図１１】



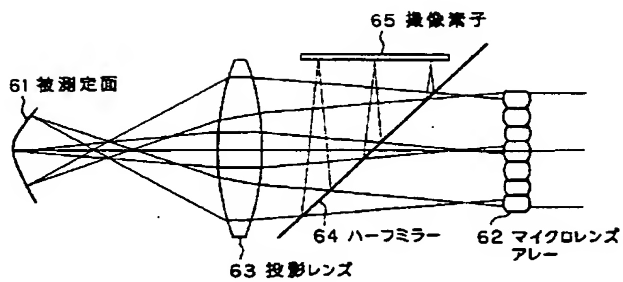
【図１３】



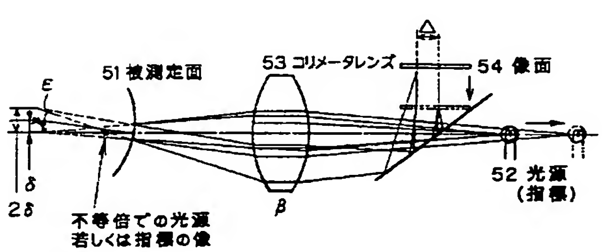
【図１６】



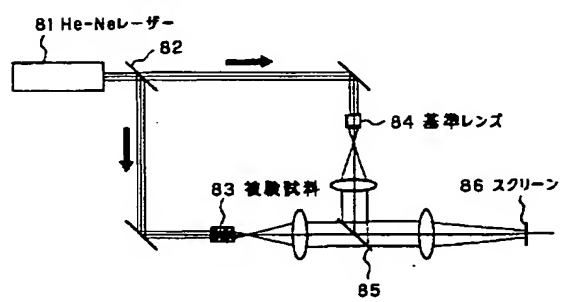
【図１４】



【図１７】



【図１８】



フロントページの続き

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